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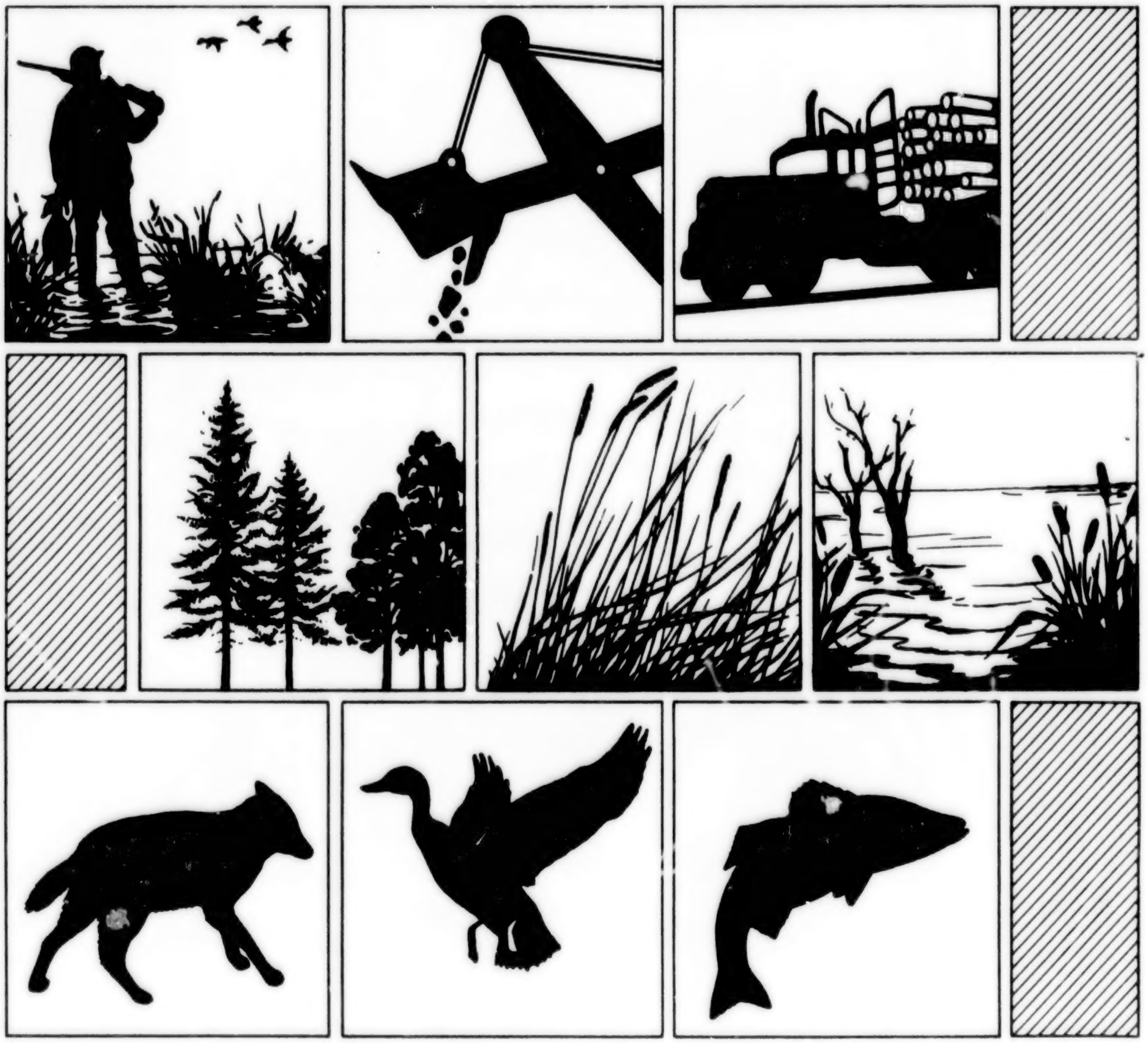
ANNOTATED BIBLIOGRAPHY OF ECOLOGICAL CUMULATIVE IMPACTS ASSESSMENT



Fish and Wildlife Service

U.S. Department of the Interior

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Biological Report 89(11)
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ANNOTATED BIBLIOGRAPHY OF ECOLOGICAL CUMULATIVE IMPACTS ASSESSMENT

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PREFACE

Federal legislative mandates to address ecological cumulative impacts (also called cumulative effects) have existed for a decade, yet the complexities of the issues have kept cumulative impacts assessment and management an elusive goal. Although documentation of research and management dealing specifically with ecological cumulative impacts is not nearly as voluminous as that concerned with traditional environmental impact assessment, valuable work has occurred that can serve as an introduction to the concepts and issues and as a foundation for the evolution of assessment strategies. Information presented here exists in published documents ranging from journal articles, symposia, and proceedings to environmental impact statements.

Interest in ecological cumulative impacts is on the increase. The first two articles with the term were published in 1975. In the period from 1975 to 1980, the publication rate was between one and four papers per year. In the period 1981 to 1984, the publication rate was between 6 and 13 papers per year. In the period from 1985 to 1988, the publication rate was between 11 and 37 papers per year, with a mean of 24 papers.

We compiled this annotated bibliography for research use as part of a cumulative impacts assessment program. Based on a number of requests, we decided to make the information more widely available. The annotations are designed to help the reader determine the usefulness of an individual reference and to provide a summary of problems and issues surrounding cumulative impacts. The annotations provide an outline of approaches taken to cumulative impacts assessment and management and a view of the present ability to successfully deal with ecological cumulative impacts.

The annotations are noted as an "abstract" if the authors of the original paper wrote it either as an abstract or as another part of their document. The annotations are noted as an "addition" if we wrote the summarization.

A combined author and title index follows the bibliography. This index is provided to facilitate selection of topics that may be of particular interest, without the need of paging through the entire text.

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ACKNOWLEDGMENTS

We are grateful for the skill and dedication of Kay Lindgren who was able to obtain even the most obscure unpublished documents. We are also grateful for the patience and word-processing skills of Dora Ibarra and Patricia Gillis.

BIBLIOGRAPHY

Ankersen, T. 1986. Cumulative impacts in Florida environmental decisionmaking. Finding the straw that breaks the camel's back (and equitably distributing all the others). Pages 235-284 in E.D. Estevez, J. Miller, J. Morris, and R. Hamman, eds. Proceedings of the conference: managing cumulative effects in Florida wetlands. New College Environmental Studies Program Publ. No. 38. Omnipress, Madison, WI.

Abstract. This paper analyzes Section 403.919, F.S., originally entitled "equitable distribution," which provides for the consideration of cumulative effects in wetlands permitting and reviews the technical basis for cumulative impact assessment and the attempts of Federal agencies and other States to account for them. Judicial and administrative cases prior to 1984 in which the Department of Environmental Regulation (DER) attempted to prevent cumulative impacts using the consistency doctrine of administrative law are analyzed. The legislative intent behind the statutory provision is determined to have been for DER to equitably distribute development rights in regulated wetlands among competing property owners. To implement this mandate, DER must develop a viable means of cumulative impact assessment and a means to allocate incremental development rights within an established threshold. Until thresholds are determined, DER might deny permits based on adverse precedent and uncertainty. Alternatively, an interim threshold with a sufficient buffer so as not to endanger the resource might be adopted. Ultimately, the paper concludes, equitable distribution requires replacement of the present ad hoc decisionmaking process with long-range resource planning.

Armour, C., R. Johnson, and S. Williamson. 1985. Problem analysis and planning for the FWS cumulative impacts program: August 1984 workshop proceedings. U.S. Fish Wildl. Serv. Biol. Rep. 85(11.1). 21 pp.

Abstract. This report presents the results of a U.S. Fish and Wildlife Service cumulative impacts assessment workshop. Workshop participants analyzed cumulative impact problems and discussed possible actions for dealing with impacts affecting fish and wildlife resources. Backstep analysis was used to analyze causes and consequences of cumulative impact problems. The functional analysis systems technique (FAST) was used to identify specific actions that could be taken to solve the problems. Actions for increasing the use of cumulative impact assessment and mitigation were categorized as: (1) increasing public understanding, (2) increasing resources devoted to cumulative impact assessment and mitigation, (3) influencing agencies to consider cumulative impacts, (4) increasing use of cumulative impact assessment by decisionmakers, (5) assembling readily available techniques and processes for cumulative impact assessment, and (6) developing new technology while integrating existing cumulative impact assessment techniques. Fifty specific actions for the six categories of action items were identified.

Armour, C.L., R.E. Ellison, R.L. Johnson, and S.C. Williamson. 1988. Description of the Fish and Wildlife Service's cumulative impacts project. Pages 211-220 in J.A. Kusler, M.L. Quammen, and G. Brooks, eds. Proceedings of the national wetland symposium: mitigation of impacts and losses. ASWM Tech. Rep. 3. Association of State Wetland Managers, Chester, VT.

Abstract (from the Introduction). A cumulative impacts research and development project was initiated by the Fish and Wildlife Service in 1984. The stimulus for the project was a priority need for improved capabilities of Ecological Services field office specialists in dealing with cumulative impacts problems. The project goals are to enhance capabilities of Ecological Services field office specialists to evaluate and understand cumulative impacts problems, to designate effective and economically feasible actions to achieve management objectives for affected resources, and to implement comprehensive plans to achieve the objectives. The purpose of this document is to review project accomplishments and to describe plans for future activities.

Bain, M.B., J.S. Irving, R.D. Olsen, E.A. Stull, and G.W. Witmer. 1986. Cumulative impact assessment: evaluating the environmental effects of multiple human developments. Argonne Nat. Lab. ANL/EES-TM-309. Argonne, IL. 71 pp.

Abstract. Cumulative impact assessment is required under several Federal laws, regulations, and court rulings. However, comprehensive analyses of the impacts of multiple human developments on the environment have been limited. The methodology proposed consists of three phases: analysis, evaluation, and documentation. In the analysis phase, matrices are used to organize data and compute relative levels of cumulative impact on affected components of the environment. The impact of a configuration (i.e., combination of development projects) is computed as the sum of all project-specific impacts, adjusted for the effect of impact interactions among the projects. The analysis phase results in a list of values representing the relative cumulative impact of every possible configuration of the proposed projects on each target resource. Such results tend to be voluminous and incommensurable, and frequently support conflicting environmental objectives. Therefore, in the evaluation phase, a computer screening program is used to identify configurations meeting the maximum cumulative impact criteria for all target resources. Iterations of this screening process can assist multidisciplinary teams in reaching agreement on a final set of cumulative impact criteria and on one or more configurations to be recommended. The documentation phase includes a concise summary of the anticipated environmental impacts of each recommendation.

Barile, D. 1986. The Indian River lagoon - seventy years of cumulative impacts. Pages 193-218 in E.D. Estevez, J. Miller, J. Morris, and R. Hamman, eds. Proceedings of the conference: managing cumulative effects in Florida wetlands. New College Environmental Studies Program Publ. No. 38. Omnipress, Madison, WI.

Abstract. The success and comfort of man's habitation of east-central Florida's Indian River lagoon region has to be related inexorably to his ability to interact with wetlands. Ancient Indian tribes and European explorers survived on estuarine productivity but had little impact on environmental systems.

The high water table of the region supported not only extensive wetlands but also massive populations of mosquitos. Fueled by the philosophy of the 1900's, large-scale projects drained inland marshes and increased freshwater flow into the estuaries. Inlets were dredged through barrier islands, and shorelines were modified. Further alteration of wetlands occurred as mangrove forests were isolated from the estuary behind dikes and levee systems. This paper documents the cumulative impacts of these trends in wetland modification. Impacts are described and related to wetland loss in both the St. John's River basin and the Indian River estuary. Subsidence, fire frequency, changes in the hydrologic cycle, water quality, and erosion are related to drainage of the St. John's River marsh system. Sedimentation, turbidity, seagrass and mangrove loss, and a fisheries decline are described for the lagoon system.

The Indian River cannot be managed as a river but as an estuary sustained by seagrass and wetland function. Coordinated information is needed to understand wetland impacts, including accurate mapping, data base development, and public awareness. Implications for cumulative impacts management include definition of watershed boundaries, coordination of drainage programs in local plans, and development of regional goals and policies. The Great Lagoon of the Ais has been lost in the guise of the Indian River. However, acknowledgment of the negative cumulative impacts of wetland alteration in the past can lead to positive cumulative impacts through research, decisionmaking, and planning.

Baskerville, G. 1986. Some scientific issues in cumulative environmental impact assessment. Pages 9-14 in Canadian Environmental Assessment Research Council and United States National Research Council. Cumulative environmental effects: a binational perspective. Minister of Supply and Services Canada.

Abstract. This paper expresses the opinion that there are two major issues to be faced in improving the scientific approach to cumulative impact assessment in terrestrial systems. First, scientific endeavours must be just that--scientific and rigorous. The essential concern here is bounding of the research and scientific interpretation at both the whole problem level and at the "piece" level. Second, impacts in biological systems accumulate in different ways. For research or scientific measurement to forecast or detect an accumulating impact the protocol must be designed in a way that is appropriate to the manner in which the impact is accumulating. In the highly variable terrestrial environment, with the highly variable terrestrial systems, over both geographic area and time, cumulative environmental impact assessment requires scientific rigor if it is to be truly useful.

Bedford, B.L., and E.M. Preston. 1988. Developing the scientific basis for assessing cumulative effects of wetland loss and degradation on landscape functions: status, perspectives, and prospects. Environ. Manage. 12:751-771.

Abstract. The incongruity between the regional and national scales at which wetlands losses are occurring, and the project-specific scale at which wetlands are regulated and studied, has become obvious. This article presents a synthesis of recent efforts by the U.S. Environmental Protection Agency and the Ecosystems Research Center at Cornell University to bring wetland science and regulation into alignment with the reality of the cumulative effects of wetland loss and degradation on entire landscapes and regions. The synthesis is drawn from the other articles in this volume, the workshop that initiated them, and the scientific literature. It summarizes the status of our present scientific understanding, discusses means by which to actualize the existing potential for matching the scales of research and regulation with the scales at which effects are observed, and provides guidelines for building a stronger scientific base for landscape-level assessments of cumulative effects. It also provides the outlines for a synoptic and qualitative approach to cumulative effects assessment based on a reexamination of the generic assessment framework we proposed elsewhere in this volume.

The primary conclusion to be drawn from the articles and the workshop is that a sound scientific basis for regulation will not come merely from acquiring more information on more variables. It will come from recognizing that a perceptual shift to larger temporal, spatial, and organizational scales is overdue. The shift in scale will dictate different- not necessarily more variables to be measured in future wetland research and considered in wetland regulation.

Betson, R.P., and T.A. Fox. 1982. Cumulative impact assessment of surface coal mining in Georgia. Pages 139-144 in F. Kilpatrick and D. Matchett, eds. Proceedings of the eastern conference on water and energy: technical and policy issues. American Society of Civil Engineers, New York, NY.

Abstract. The Surface Mine Reclamation and Control Act of 1977 (PL 95-87) requires that an assessment be conducted of the probable cumulative impacts of all anticipated coal mining in the area upon the hydrology of the area. A simplified approach is proposed for considering potential impacts to sedimentation, and a methodology is presented for evaluating the potential water quality impacts based upon predicted changes to pH. The methodology is demonstrated with an assessment conducted for northwest Georgia.

Bonnicksen, T.M. 1980. Computer simulation of the cumulative effects of brushland fire-management policies. Environ. Manage. 4:35-47.

Abstract. A mathematical model simulates the cumulative volume of debris produced from brushland watersheds. Application of this model to a 1.76 km^2 watershed along the southern flank of the Central San Gabriel Mountains permits assessment of expected debris production associated with alternative fire-management policies. The political implications of simulated debris production are evaluated through a conceptual model that links interest groups to particular successional stages in brushland watersheds by means of the resources claimed by each group. It is concluded that, in theory, a rotation burn policy would provide benefits to more interest groups concerned about southern California brushland watersheds than does the current fire exclusion policy.

Brinson, M.M. 1988. Strategies for assessing the cumulative effects of wetland alteration on water quality. Environ. Manage. 12:655-662.

Abstract. Assessment of cumulative impacts on wetlands can benefit by recognizing three fundamental wetland categories: basin, riverine, and fringe. The geomorphological settings of these categories have relevance for water quality. Basin, or depressional, wetlands are located in headwater areas and capture runoff from small areas. Thus, they are normally sources of water with low elemental concentration. Although basin wetlands normally possess a high capacity for assimilating nutrients, there may be little opportunity for this to happen if the catchment area is small and little water flows through them. Riverine wetlands, in contrast, interface extensively with uplands. It has been demonstrated that both the capacity and the opportunity for altering water quality are high in riverine wetlands. Fringe wetlands are very small in comparison with the large bodies of water that flush them. Biogeochemical influences tend to be local, rather than having a measurable effect on the larger body of water. Consequently, the function of these wetlands for critical habitat may warrant protection from high nutrient levels and toxins, rather than expecting them to assume an assimilatory role.

The relative proportion of these wetlands types within a watershed and their status relative to past impacts can be used to develop strategies for wetland protection. Past impacts on wetlands, however, are not likely to be clearly revealed in water quality records from monitoring studies, either because records are too short or because too many variables other than wetland impacts affect water quality. It is suggested that hydrologic records be used to reconstruct historical hydroperiods in wetlands for comparison with current, altered conditions. Changes in hydroperiod imply changes in wetland function, especially for biogeochemical processes in sediments. Hydroperiod is potentially a more sensitive index of wetland function than surface areas obtained from aerial photographs. Identification of forested wetlands through photointerpretation relies on vegetation that may remain intact for decades after drainage. Finally, the depositional environment of wetlands is a landscape characteristic that has not been carefully evaluated nor fully appreciated. Impacts that reverse depositional tendencies also may accelerate rates of change, causing wetlands to be large net exporters rather than modest net importers. Increases in rates as well as direction can cause stocks of materials, accumulated over centuries in wetland sediments, to be lost within decades, resulting in nutrient loading to downstream aquatic ecosystems.

Brown, M.T. 1986. Cumulative impacts in landscapes dominated by humanity. Pages 33-50 in E.D. Estevez, J. Miller, J. Morris, and R. Hamman, eds.

Proceedings of the conference: managing cumulative effects in Florida wetlands. New College Environmental Studies Program Publ. No. 38. Omnipress, Madison, WI.

Abstract. Concepts of cumulative impacts are explored and defined. Organizational principles of landscapes are given and applied to the Florida landscape. Problems associated with development in low and high relief watersheds are explored, and cumulative impacts on watersheds, wetlands, and water are explained. The major cumulative effects of increasing human utilization of the landscape are the drying out of land and loss of headwater functions. These impacts result in changing species composition of ecosystems and loss of valuable ground and surface waters. A program of monitoring and managing cumulative impacts is proposed.

Cada, G.F., and R.B. McLean. 1985. An approach for assessing the impacts on fisheries of basin-wide hydropower and development. Pages 367-372 in F.W. Olson, R.G. White, and R.H. Hamre, eds. Proceedings of the symposium on small hydropower and fisheries. American Fisheries Society, Western Division and Bioengineering Section.

Abstract. An application of a matrix technique to the assessment of hydropower impacts on resident trout in the upper San Joaquin River basin in California is presented. Advantages and limitations of the approach as a tool for evaluating multiple-project impacts are described. Recommendations are made for further development of the matrix technique for use in basin-level cumulative impact assessments.

Addition. Impacts in the matrix were weighted according to damage they cause to the aquatic habitat. The analysis identified four factors that were considered to be important in regulating trout populations and that could be altered by construction or operation of the projects: sedimentation potential, cover loss, restriction of movement, and loss of food base. The effects of each project on these components are discussed as well as the benefits of mitigative measures. An analysis of the usefulness of the matrix technique for systematically organizing and displaying the results of environmental impact assessments is provided.

Camp, H.W. 1981. A summary of the Edgebrook Conference on cumulative effects of forest management on California watersheds. Pages 105-109 in R.B. Standiford and S.I. Ramacher, eds. Cumulative effects of forest management on California watersheds. Univ. Cal. Agri. Sci. Spec. Publ. 3268. Berkeley.

Addition. The Edgebrook Conference was convened in response to repeated expressions of need for such a conference by resource managers and groups, agencies, and individuals concerned with the welfare of the State's watersheds. The conference was designed to address the questions of what is known and to identify information needs regarding cumulative effects on resource systems. In the summary, cumulative effects is defined, the present status of knowledge is described, and a proposed list of studies based on information needs is provided.

Campbell, D. 1983. The cumulative effects of small scale hydropower. Pages 65-70 in P. Dyer, ed. Small scale hydropower: how does it fit in the Northwest energy/environmental picture? University of Washington, Seattle.

Addition. The author describes four categories of cumulative impacts from small hydropower: (1) cumulative adverse effects involving individual small hydro sites, (2) cumulative impacts that result from several small hydro plants in one stream, (3) the cumulative adverse effects of all the small hydropower plants that will be constructed in North America, and (4) the cumulative "paperwork effect" of 4,000 or more permit applications submitted during the past several years. The author also gives a brief rebuttal to the high energy demands forecast in the Pacific Northwest presented earlier in the program.

Canadian Environmental Assessment Research Council. 1988. The assessment of cumulative effects: a research prospectus. Minister of Supply and Services Canada. Cat. No. En 106-10/1988. 11 pp.

Abstract (from the Introduction). Canadian Environmental Assessment Research Council (CEARC) has placed cumulative effects assessment (CEA) high on its agenda of research priorities for a number of reasons. First and foremost is the difficulty of undertaking sound EIA (environmental impact assessment) without consideration of the regional context and cumulative changes resulting from multiple impacts. Second, CEA reflects a number of the research themes adopted by CEARC to guide its activities, namely the integration of assessment within a broader planning context; improvements in the rigour of scientific analysis; and the strengthening of institutional frameworks. Third, CEARC has decided to give priority to problems that cut across conventional scientific and institutional boundaries and impede current practice. Fourth, CEARC is interested in promoting research in issues that fall outside the mandates of other research granting agencies. Finally, CEARC is developing approaches for evaluating environmental impacts of broad policies in addition to specific projects. CEA is a good example of all these interests; it underlines the need for a well organized and long-term approach leading towards a resolution of the scientific and institutional aspects of the problem.

We begin with a brief summary of some background studies and workshops sponsored by CEARC to develop a better understanding of the concept of cumulative effects assessment and an evaluation of current practice in Canada and elsewhere. Based on this review, some immediate research needs are identified. Finally, we present the Council's agenda for CEA research, set in the context of its overall strategy for improving performance and practice of environmental assessment in Canada. Appendix A outlines a conceptual perspective on cumulative effects.

Canadian Environmental Assessment Research Council and United States National Research Council. 1986. Cumulative environmental effects: a binational perspective. Minister of Supply and Services Canada. 175 pp.

Abstract (from the Introduction). Cumulative effects of multiple environmental perturbations of natural and social systems were identified by CAETEP (Committee on the Applications of Ecological Theory to Environmental Problems) and CEARC as needing study because there did not appear to be any clear and unambiguous definition of cumulative effects assessment, despite the widespread recognition of its importance. In addition, there is increasing concern that neither scientists nor institutions work at the temporal and spatial scales needed for the assessment of cumulative effects. In short, traditional project-specific environmental assessment is not adequate for many environmental problems resulting from multiple perturbations that often involve several jurisdictions.

The purpose of the Toronto workshop was to explore these issues, to identify current scientific and management techniques of dealing with cumulative effects, and to recommend research and management priorities for improving the management of cumulative effects. The workshop organizers sent a letter to all participants, asking for contributions, and noting the shortcomings of environmental assessment that is focused on specific projects:

- It ignores the additive effects of repeated developments in the same ecological systems, e.g., the effects of the loss of wetlands and disposal of toxic chemicals on fish habitats and productivity.
- It does not deal adequately with precedent-setting developments that stimulate other activities, especially in fragile environments.
- It ignores change in the behavior of ecological systems in response to increasing levels of perturbation, e.g., nonlinear functional relationships.
- It does not encourage the development of comprehensive environmental objectives that reflect the broad goals of society.

[See also: Baskerville; Clark; Dayton; Glanz and McKay; O'Riordan; Waldichuk.]

Canter, B. 1986. Models for cumulative effects management in nonwetland regulatory programs. Pages 285-297 in E.D. Estevez, J. Miller, J. Morris, and R. Hamman, eds. Proceedings of the conference: managing cumulative effects in Florida wetlands. New College Environmental Studies Program Publ. No. 38. Omnipress, Madison, WI.

Abstract. An investigation of Florida's nonwetland regulatory programs revealed that essentially none of them manage cumulative effects the way cumulative effects to wetlands are managed. Under nonwetland regulatory programs, only the cumulative effects of past development activities are considered when a new activity in wetlands is proposed. No attempt is made to

account for possible future cumulative effects on the same resource. Outside the wetlands regulatory program, the prediction of future effects plays no significant role in permit decisionmaking. This pattern suggests that the current predictive approach to wetland management might be inherently impractical, and better management could be achieved with an alternative approach using regulatory principles derived from the nonwetland regulatory programs. The manner in which cumulative effects are managed under Florida's water use, water quality, and air quality programs is examined. A regulatory framework for wetlands protection is outlined, using these nonwetland programs as models.

Carstea, D., S. Golden, and L. Thomas. 1975. Guidelines for the analysis of cumulative environmental effects of small projects in navigable waters. Mitre Corporation Tech. Rep. MTR-6939. McLean, VA. v.p.

Addition. This manual deals specifically with the construction of a recreational boat mooring area, without the availability of water-oriented activities, within a nonrecreational boating area. The procedures quantify the effects of project construction and utilization on navigation, noise, air quality, water quality, and socioeconomics and depend on a detailed knowledge of the existing quality of these parameters. Statistical, dispersion, dilution, and diffusion models are used to predict water pollutant loads, emissions effects on ambient air quality, and navigational profiles. Vehicular traffic, expenditures, visual quality, and taxation were investigated to determine impacts on socioeconomics. An actual case was used to exemplify the procedures throughout the manual.

Cederholm, C.J., L.M. Reid, and E.O. Salo. 1981. Cumulative effects of logging road sediment on salmonid populations in the Clearwater River, Jefferson County, Washington. Pages 38-74 in Proceedings of the conference on salmon spawning gravel: a renewable resource in the Pacific Northwest. State of Washington Water Research Center, Rep. No. 39, Pullman, WA.

Abstract. The nature of sediment production from logging roads and the effect of the resulting sediment on salmonid spawning success in the Clearwater River drainage have been studied for 8 years. The study includes intensive and extensive analyses of field situations, supplemented by several controlled experiments. It was found that significant amounts (15%-25%) of fine sediments (less than 0.85 mm diameter material) are accumulating in spawning gravels of some heavily roaded tributary basins. This accumulation is highest in basins where the road area exceeds 2.5% of the basin area. Tributaries of relatively steep gradient are less likely to accumulate high levels of fines. The survival of salmonid eggs to emergence is inversely correlated with percent fines when the percentage of fines exceeds the natural levels of 10%. There is a rapid decrease in survival to emergence for each 1% increase in fines over natural levels. The presence of 2.5 km/km^2 of gravel-surfaced roads undergoing an average distribution of road uses is found to be responsible for producing sediment at 2.6-4.3 times the natural rate in a drainage basin. Sixty percent of the road-related sediment production is caused by landslides, while erosion on road surfaces accounts for an additional 18%-26%. If fine sediment alone is considered, production from road surfaces and landslides is nearly equal. The tributaries of the Clearwater River may be underseeded for coho salmon due to heavy harvest rates in the commercial and sport fisheries. This underseeded condition becomes significant when the efficiency of the spawning environment in producing recruits is lowered by logging-caused sedimentation.

Christensen, A.G. 1986. Cumulative effects analysis: origins, acceptance, and value to grizzly bear management. Pages 213-216 _in_ G.P. Contreras and K.E. Evans, eds. Proceedings - grizzly bear habitat symposium. U.S. Forest Service Intermountain Research Station General Technical Report INT-207.

Abstract. The cumulative effects analysis process developed on the Kootenai National Forest was born of need generated by proposals for access and activity in critical grizzly bear habitat. It has been applied to the analysis of extremely controversial projects involving hard rock mineral exploration and has been the focus of conflict between rights granted in the 1872 Mining Law and responsibilities of Federal agencies under the Endangered Species Act of 1973. Despite suits and threats of suits from developmental and environmental interests, the process has been accepted and utilized by Forest Service land managers. This paper outlines the process and explores the application of cumulative effects analysis to Forest activities over the past three years and how that application has assisted in making sensitive land management decisions. It also suggests that analysis of land management activities has been permanently altered by applying a cumulative effects perspective.

Christensen, A.G., and M.J. Madel. 1982. A cumulative effects analysis process for grizzly bear habitat, Cabinet Mountains, Montana. Pages 124-132 _in_ R.D. Comer, J.M. Merino, J.W. Monarch, C. Pustmueller, M. Stalmaster, R. Stoecker, J. Todd, and W. Wright, eds. Issues and technology in the management of impacted western wildlife. Tech. Publ. No. 14, Thorne Ecological Institute, Boulder, CO.

Abstract. Historic declines in grizzly bear populations and current pressure on remaining population centers are primarily associated with man-caused activities. Multiple use land management agencies are legally bound to respond to laws that may provide conflicting guidance in a specific geographical area. A technique for analyzing the cumulative effects of all known man-caused activities on grizzly bear habitat in the Cabinet Mountains of Montana provided a better perspective for making resource management decisions and complying with existing laws. The quantity, location, and seasonal importance of 13 habitat components based on food and denning requirements were plotted on project maps and data sheets for eight bear units totaling about 2,085 km^2. Systematic analysis of habitat component maps with clear plastic activity proposal overlays provided a basis for quantifying available space, food, and denning habitat for grizzly bears at any time. Analysis of all eight bear units provided a better perspective on the condition of grizzly bear habitat in the Cabinet Mountains and spotlighted core habitat areas and problem areas. The technique should be applicable to other species with known habitat needs.

Christensen, A.G., and M.J. Madel. 1984. Cumulative effects analysis process and grizzly habitat component mapping. U.S. Forest Service, Kootenai National Forest, Libby, MT. 75 pp.

Addition. The main objectives of this analysis were to develop a method for systematically analyzing the effects of various existing and proposed human-related activities on grizzly bear habitat, and to develop a rationale and process that provides perspective on the viability of grizzly habitat as it is influenced by various human-related activities. These objectives were accomplished by identifying and quantifying recognized grizzly bear habitat in the analysis area, identifying the parameters of viable habitat based on data extrapolated from other areas, and devising a format and technique for analyzing the human-related activities. The analysis area was about 515,000 acres, including the main Cabinet Mountains range and essentially all of the West Cabinets or Scotchman Peaks in northwestern Montana. Prior shortcomings that plagued the management of grizzly habitat in concert with human activities were addressed, including: the ability to quantify components by season of importance, an upper and lower limit of spatial needs, and an analysis procedure that recognized all ongoing activities. The analysis description includes maps, sample data and analysis sheets, and data on home range for 13 adult female grizzlies.

The second part of the report describes the techniques and procedures for identifying, mapping, and displaying habitat components and other pertinent information, and provides descriptions of habitat components classified for the Cabinet Mountains, with their relative seasonal values. Criteria used to evaluate habitat components included direct field evidence of bear use, information from research studies in western Montana, and the average availability and abundance of key foods. Sample forms and maps are provided. An addendum provides component descriptions for the Whitefish Range of the Flathead National Forest.

Clark, W.C. 1986. The cumulative impacts of human activities on the atmosphere. Pages 113-124 in Canadian Environmental Assessment Research Council and United States National Research Council. Cumulative environmental effects: a binational perspective. Minister of Supply and Services Canada.

Addition. This paper summarizes recent work in atmospheric impact studies for scientists and managers in other fields of environmental assessment who might benefit from these experiences. A conceptual framework that includes an introduction to terminology of cumulative impacts is described, followed by a synoptic perspective on atmospheric impact assessment. The synopsis is meant to show how valued atmospheric components are related to sources of atmospheric disturbance. The author then explores the significance of cumulative impacts that arise from multiple sources of environmental disturbance. The use of synoptic matrices in simple or complex assessments is shown with an example, and a discussion of row and column summation assessment is provided within this context. The origin of cumulative impacts in relation to temporal and spatial scale is analyzed. Mesoscale, synoptic scale, and global scale constituents are shown graphically and discussed. The author concludes that the tendency to adopt a cumulative perspective is further and more generally advanced in atmospheric studies than in other disciplines, due largely to the relatively strong foundations in basic, as opposed to applied, research.

Clark, J.R., and J.A. Zinn. 1978. Cumulative effects in environmental assessment. Pages 2481-2492 in American Society of Civil Engineers, ed. Coastal zone. ASCE, New York, NY.

Abstract. Impact assessment can be facilitated by the use of a step-by-step system designed to embrace the full range of effects of projects of varying size. The system should include secondary and cumulative effects. It should be based on clear concepts and unambiguous language. Such a system is presented here.

Cline, E.W., E.C. Vlachos, and G.C. Horak. 1983. State-of-the-art and theoretical basis of assessing cumulative impacts on fish and wildlife. Prepared for the U.S. Fish and Wildlife Service, Eastern Energy and Land Use Team, Kearneysville, WV. Contract No. 14-16-0009-81-058. 69 pp.

Addition. This document is one of three prepared to identify and summarize the state-of-the-art biological assessment and monitoring of cumulative effects of development on fish and wildlife populations and habitats. This document is aimed primarily at the research scientist and academician. The present knowledge of cumulative impact efforts is outlined, and a theoretical and definition basis of cumulative impact assessments is derived. Present inadequacies of the process, needed research efforts, major problem areas, and methodological similarities are summarized.

Coats, R.N., and T.O. Miller. 1981. Cumulative silvicultural impacts on watersheds: a hydrologic and regulatory dilemma. Environ. Manage. 5:147-160.

Abstract. Because of the nature of watersheds, the hydrologic and erosional impacts of logging and related road-building activities may move offsite, affecting areas downslope and downstream from the operation. The degree to which this occurs depends on the interaction of many variables, including soils, bedrock geology, vegetation, the timing and size of storm events, logging technology, and operator performance. In parts of northwestern California, these variables combine to produce significant water quality degradation, with resulting damage to anadromous fish habitat.

Examination of recent aerial photographs, combined with a review of public records, shows that many timber harvest operations were concentrated in a single 83 km^2 watershed in the lower Klamath River Basin within the past decade. The resulting soil disturbance in this case seems likely to result in cumulative off-site water quality degradation in the lower portion of the basin.

In California, both State and Federal laws require consideration of possible cumulative effects of multiple timber harvest operations. In spite of recent reforms that have given the State a larger role in regulating forest practices on private land, each timber harvest plan is still evaluated in isolation from other plans in the same watershed. A process of collaborative State-private watershed planning with increased input of geologic information offers the best long-term approach to the problem of assessing cumulative effects of multiple timber harvest operations. Such a reform could ultimately emerge from the ongoing water quality planning process under Section 208 of the amended Federal Water Pollution Control Act.

Cohrssen, J.J., F.H. Irwin, B.A. Lyons, G. Reyes, G. Robarge, and B. Rodes. 1989. Inventory of Federal agency activities on cumulative impact assessment and summary of November 30, 1988 interagency meeting on cumulative impact assessment. Prepared under contract for the Council on Environmental Quality. The Conservation Foundation, Washington, D.C. 206 pp.

Abstract. The inventory compiles seven categories of information related to cumulative impact assessment for each of 22 Federal agencies: (1) current activities in cumulative impact assessment; (2) legal provisions; (3) guidance; (4) court cases; (5) examples of environmental impact statements that assess cumulative impacts; (6) related literature; and (7) key agency contacts. The report also includes abstracts of the guidance, court cases, environmental impact statements, and related literature.

An introduction to the inventory discusses the difficulty of defining cumulative impacts and the influence of court decisions on cumulative impact assessment. Agencies are at an early stage of learning when and how to analyze cumulative impacts. The introduction highlights examples of ways in which agencies are beginning to address cumulative impacts, including: (1) preparing guidance; (2) conducting research and holding workshops; and (3) preparing and reviewing environmental impact statements. The appendix is a summary of the November 30, 1988 interagency meeting on cumulative impact assessment.

Conover, S.A.M., K.W. Strong, T.E. Hickey, and F. Sander. 1985. An envolving (sic) framework for environmental impact analysis. I. Methods. J. Environ. Manage. 21:343-358.

Abstract. A framework for biophysical environmental impact analysis has been developed that is applicable to simple and complex situations, employs a systematic approach, allows for the application of sophisticated analytical techniques when and where justified, and provides an appreciation of the limitations of the possible. It is equally applicable to terrestrial and aquatic environments, and can accommodate direct and indirect effects, positive and negative impacts, and concerns at the individual, population, species, and ecosystem levels. It can recognize additive, repetitive, chronic, and synergistic ("cumulative") impacts. Potential impacts are evaluated using a predetermined set of ecologically based impact definitions. Definition of spatial, temporal, and population boundaries is also essential to the analysis. The framework itself consists of an eight-step procedure: project description, description of environmental conditions, identification of potential project-environment interactions, detailed investigation of relevant project attributes, detailed investigation of relevant environmental attributes, impact evaluation, identification of potential mitigation measures, and evaluation of potential residual impacts.

Conover, S.A.M., K.W. Strong, T.E. Hickey, and F. Sander. 986. An evolving framework for environmental impact analysis. II. Applications. J. Environ. Manage. 21:359-374.

Abstract. The concepts described in the accompanying paper (Conover et al. 1985) were applied to four potential environmental impact examples. The examples included one each for the Zone of Direct Physical Disturbance, the Zone of Influence of Routine Discharges, the Zone of Influence of Accidental Releases, and an approach to analysis of "cumulative" effects within a Zone of Influence of Routine Discharges. Examples were deliberately chosen from both terrestrial and aquatic environments to demonstrate the applicability of the approach to all environments. Each problem was analyzed using the eight-step approach described in the previous paper.

The adjective "evolving" should be stressed when considering this framework for impact analysis. Impact analysis is still in a primitive state, but this framework allows systematic handling of the procedure, and clarifies where and when to apply the more sophisticated types of analysis that are becoming available for use in impact evaluation, application of mitigation measures, monitoring programs, and determining acceptability of residual impacts.

Contant, C.K. 1984. Cumulative impact assessment: design and evaluation of an approach for the Corps of Engineers permit program at the San Francisco District. Ph.D. Dissertation. Stanford University, Palo Alto, CA. 373 pp.

Abstract. Federal agencies have been required to assess the environmental impacts of proposed development projects since the passage of the National Environmental Policy Act in 1969. Included in these assessments is a consideration of the "cumulative impacts" of proposed development, since projects with individually minor impacts may have collectively significant effects. An approach is designed, implemented, and formally evaluated for cumulative impact assessment (CIA) of construction projects under the authority of the U.S. Army Corps of Engineers Permit Program. Two features form the basis of the proposed CIA approach: (1) a carrying capacity study to determine limits to development, and (2) worksheets used during permit review to identify project impacts systematically. This approach was implemented at the San Francisco District with a carrying capacity study performed on the Oakland Estuary, where the critical limiting factor was found to be boating congestion.

Evaluation efforts focused on the implementability of the approach and the effects of using the approach in permit evaluation. Implementation was monitored with appraisals made of the approach's use of resources and personnel, and of its appropriateness in the permit process. A detailed quasi-experimental design was employed to test a priori hypotheses on the effects of using the CIA approach in permit review. Detailed measures, scoring systems, and data analysis were established for the nine variables addressed in these hypotheses. Due to economic conditions during the field study, only two cases using the CIA approach were available for analysis. Since statistical arguments were not possible, qualitative case descriptions were prepared and analyzed. Results indicate that the process of permit review incorporated more information than necessary for cumulative impact consideration. Other results indicated that a more "appropriate" structure for permit review resulted from implementing the CIA approach.

Conclusions drawn from this field study were twofold. First, the evaluation procedure provided valuable information for understanding the process of cumulative impact assessment. Second, the proposed CIA approach succeeded, in a limited sense, in incorporating information on cumulative impacts in permit review. Final observations note the value of a carrying capacity framework to structure discussions necessary for a cumulative impact assessment.

Contant, C.K., and L. Ortolano. 1985. Evaluating a cumulative impact assessment approach. Water Resour. Res. 21:1313-1318.

Abstract. A new procedure was formulated to predict and monitor the cumulative impacts of projects requiring Corps of Engineers permits. To evaluate the effectiveness of this new assessment approach, hypotheses describing relationships between an independent variable, use of the cumulative impact assessment approach, and nine dependent variables were developed. A quasi-experiment, in which the cumulative impact assessment approach was the treatment, was conducted to determine how the approach influenced the permit review process. The evaluation procedure was applied to the test implementation of the cumulative impact assessment approach at the San Francisco District. Measures and scoring procedures were devised and data were collected and analyzed. Conclusions regarding the new approach were drawn along with suggestions for improvements to the evaluation procedure.

Craig, N.J., and J.W. Day, Jr. 1976. Barataria Basin: eutrophication case history. Prepared by the Center for Wetlands Resources, Louisiana State University, Baton Rouge. NOAA-77021608. Office of Coastal Zone Management, National Oceanic and Atmospheric Administration, Rockville, MD. 24 pp.

Abstract. The cumulative impact of eutrophication and salinity changes on the nursery grounds of the Barataria Basin were assessed. Much of man's activity in the coastal zone leads to salinity change or the introduction of excessive nutrients into water bodies. Various factors producing these impacts are identified, and the relative importance of each of these factors is quantified. Predictions about future impacts are based on the continuation of present trends and mitigation possibilities. The Barataria Basin is an inter-distributary bay-wetland system bordered by Bayou Lafourche, the Mississippi River, and the Gulf of Mexico. The coastal wetlands of Barataria Basin, extending from the fresh swamp of the upper basin to the saline marsh bordering the coast, serve as water storage reservoirs, nursery areas, chemical transformation factories, and sources of organic matter and nutrients. The importance of the estuaries as nursery grounds cannot be overstressed. Barataria Basin alone is responsible for about 45% of Louisiana's total commercial fishery harvest.

Craig, N.J., and J.W. Day, Jr. 1977. Cumulative impact studies in the Louisiana coastal zone: eutrophication, land loss. Coastal Resources Program Rep. No. NOAA-77092107. Office of Coastal Zone Management, Louisiana State Planning Office, Baton Rouge. 166 pp.

Abstract. Eutrophication is a widespread problem throughout the coastal zone of Louisiana. It leads to poor water quality, development of nuisance algal blooms, decline in desirable commercial and sports fishery species, and diminished recreational usefulness of water bodies. The major cultural sources of nutrients leading to eutrophication are urban runoff, domestic sewage, and agricultural runoff. Basins across the coastal zone were examined for water quality. Lake Pontchartrain Basin, Barataria Basin, Terrebonne Basin, Atchafalaya Basin, and Calcasieu Basin all had serious problems of eutrophication.

Eutrophication can be controlled and is reversible. If direct introduction of nutrient-laden water into aquatic bodies is eliminated, the water bodies will eventually return to a less eutrophic state. The length of time for this to take place depends on the duration and intensity of historical nutrient input. Land treatment (overland flow) offers a viable means of treatment of nutrient wastes.

The understanding and solution of the problem of eutrophication in the coastal zone must be considered within the context of the hydrologic unit. The whole drainage basin or watershed must be considered the fundamental unit of study. We have outlined a methodology (trophic state analysis) that we believe can be used to classify water bodies in the coastal zone according to trophic status.

Dames and Moore. 1981. Methodology for the analysis of cumulative impacts of permit activities regulated by the U.S. Army Corps of Engineers. Prepared for U.S. Army Corps of Engineers, Institute for Water Resources, Fort Belvoir, VA. Contract DACW72-80-C-0012. v.p.

Addition. This is a draft, detailed handbook. The introduction reviews the legal basis for the requirement to analyze cumulative impacts; provides definitions for cumulative impact concepts; and uses impacts by Corps-permitted activities as examples. Direct, secondary, indirect, future, aggregative, and growth-inducing impacts are discussed. Specific identifications that are necessary to characterize the permit activity and major biotic features that must be noted at the organism, population, and community levels of the ecosystem are described. Because the Council on Environmental Quality mandated the use of tiering (fitting the scope and depth of the analysis to the subject of the assessment), the methodology in the handbook applies this concept to cumulative impact assessment. Tiering is described in detail, and the major impacts of specific structures and projects are outlined. The analysis of growth-inducing permits and growth accommodating permits is described step-by-step. Impact network diagrams for 14 activities are provided, as well as tables that describe parameters, impact magnitude, and scale for 11 activities and various ecosystems. The appendices provide supplemental information for environment characterization and for estimating the significance of biological effects; characteristics of growth-inducing actions, regional growth patterns, and local infrastructure and land use; tools for dealing with uncertainty; economic forecasting techniques and models; and various economic, impact, and land use models.

Dayton, P.K. 1986. Cumulative impacts in the marine realm. Pages 79-84 in Canadian Environmental Assessment Research Council and United States National Research Council. Cumulative environmental effects: a binational perspective. Minister of Supply and Services Canada.

Abstract (from the Introduction). The objective of this essay is to consider the evaluation of cumulative environmental impacts of various man-caused perturbations to marine ecosystems. Specifically, I discuss the scientific perspective of cumulative impact assessments of marine environments with special regard to issues of scale, techniques and recommendations for the future. I assume that an implicit objective is to consider cumulative impact assessments as they relate to long-term stability (in the general sense) of marine ecological communities.

Dennis, N.B. 1986. Industrial and commercial development in diked historic tidelands of San Francisco Bay: the need for assessment of cumulative impacts. Pages 191-197 in J.A. Kusler and R. Riexinger, eds. Proceedings of the national wetland assessment symposium. ASWM Tech. Rep. 1. Association of State Wetland Managers, Chester, VT.

Addition. This report is concerned with the impacts of developments in diked wetlands, where the majority of new developments are occurring, rather than tidal wetlands. The author provides a historic context of settlement as well as descriptions of commercial, industrial, smoke stack, and electronic industries. The impact assessment method is outlined in four basic steps: (1) describe precisely the project dimensions, actions, and specific facilities; (2) inventory and describe wetlands; (3) determine specific impact relationships between project facilities and operations, and specific areas and conditions of the site; and (4) outline options for mitigating impacts and conditioning permits. These steps are detailed in the paper. The author suggests these development proposals are not typical and thus must be subjected to another level of impact assessment and mitigation planning.

Denslow, S., P. Goode, D. Younger, M. Feldman, S.R. Braund, and D.C. Burnham. 1985. Review of cumulative impact assessment literature and North Slope Borough development projects. U.S. Department of the Interior, Minerals Management Service. Alaska Outer Continental Shelf Region OCS Special Report No. 5. 459 pp.

Abstract. This report reviewed a diverse group of environmental assessment literature to determine its potential applicability to assessment of the cumulative impacts of oil, gas, and other industrial and community development projects on the communities of the North Slope Borough. While it was initially hoped this review would yield a specific methodology that could be implemented by Mineral Management Service (MMS) in its next Outer Continental Shelf lease sale assessment, no such methodology was uncovered. Instead, the literature revealed a set of difficulties that highlighted the inappropriateness of using any one method to assess the effects of large, technologically complex projects in the rapidly changing and relatively poorly understood human environment of the North Slope Borough. However, the review did yield a set of six general approaches and several observations that could help MMS develop a new framework for subsequent cumulative impacts analyses. Some of these approaches are similar to the current set of methods used by MMS. Others are different, and would require changes not only in the specific methods used to conduct assessments, but also in the overall policies that guide the MMS environmental assessment program.

Dickert, T.G., and A.E. Tuttle. 1985. Cumulative impact assessment in environmental planning: a coastal wetland watershed example. Environ. Impact Assess. Rev. 5:37-64.

Abstract. Several theoretical, analytical, and institutional difficulties have impeded the development and application of the assessment of cumulative environmental impacts. Watershed development on coastal wetlands offers an ideal context for evaluating the land disturbance target approach to cumulative impact assessment. A model land use planning system involving a time series approach was developed for Elkhorn Slough in California. The approach included four major components: evaluation of erosion susceptibility, measurement of land disturbance, establishment of a land disturbance target, and a comparison of existing and target land disturbance values. Further research is needed to test the transferability of the approach in a wide range of coastal watersheds and to verify the applicability of the methods to other cumulative impact problems.

Driscoll, A.L. 1979. Snohomish estuary wetlands study. Vol. I. Summary report. Shapiro and Associates, Inc., Seattle, WA.

Abstract. This study provides a basis for the environmental evaluation of public interest factors and a factual body of physical, biological, public policy, and land use information for the Snohomish estuary study area, to be used in the environmental evaluation and review of Corps Section 10 and Section 404 permit applications. Wetlands and areas of particular importance or concern in the study area are identified and described. A method for the assessment of the specific and cumulative impacts of proposed permit activities is presented. The study area includes the entire 100-year floodplain of the Snohomish River north of its confluence with Ebey Slough, Everett Harbor, the north shore of Possession Sound including Tulalip Bay and adjacent upland boundaries. Emphasis is on the floodplain and areas under Corps jurisdiction; the upland areas are included because activities there may influence wetlands and floodplain areas. The permit review process as carried out by the Seattle District is described.

Eckberg, D.K. 1985. Cumulative impacts of hydropower development under the National Environmental Policy Act: the requirements of a basin-wide approach. Pages 357-366 in F.W. Olson, R.G. White, and R.H. Hamre, eds. Proceedings of the symposium on small hydropower and fisheries. American Fisheries Society, Western Division and Bioengineering Section.

Addition. This paper discusses cumulative impacts of small hydropower in terms of legislation and court cases. Cumulative impacts is defined, the cumulative impacts of hydropower are discussed, and the existing administrative consideration of cumulative impacts is outlined. The author contends that a complete analysis of hydropower development under NEPA should include discussion of an issue related to cumulative impacts--project segmentation. He provides a suggested approach that the Federal Energy Regulatory Commission should employ to fulfill its NEPA responsibilities.

Eckberg, D.K. 1986. Cumulative impacts of hydropower development under NEPA. Environmental Law 16:673-703.

Abstract. Federal legislation, aimed at encouraging the development of renewable energy resources, has produced an unprecedented national hydropower boom, leading hydropower project developers to propose the construction of multiple projects on single river basins throughout the country. Other users of the river basins and Federal and State planning agencies have become increasingly concerned that the cumulative impacts of these projects might destroy important river resources such as migrating fish stocks, wildlife, and recreational pursuits. The Federal Energy Regulatory Commission (FERC) is responsible for authorizing these projects. This article suggests that to comply with NEPA and thereby eliminate the unnecessary degradation of important river resources, FERC should assess hydropower development on a basin-wide scale, considering the cumulative impacts of all hydropower preliminary permits, licenses, exemptions, and non-hydropower activities affecting common river resources.

Emery, R.M. 1986. Impact interaction potential: a basin-wide algorithm for assessing cumulative impacts from hydropower projects. J. Environ. Manage. 23:341-360.

Abstract. The U.S. Federal Energy Regulatory Commission has proposed a "Cluster Impact Assessment Procedure" (CIAP) for analyzing cumulative impacts from hydropower projects on the resources of a river basin. While the CIAP is based on analyses of perceived magnitudes of impacts, it avoids any interpretation of the potential for basin-wide interaction among the projects leading to an accumulation of their effects in the resources. A measure of an "impact interaction potential" (IIP) is suggested here to describe the functional side of cumulative impacts. This tendency of a project cluster to cause cumulative impacts, or its "cumulativity", is examined through subbasin disaggregations of projects and resources. A dispersion of the project's impacts across subbasins is evaluated using linear algebra and principles of information theory. The formalized algorithm is programmed in BASIC and proposed as an IIP Assessment Loop in the CIAP. The IIP Loop attaches to the Multiple Project

Assessment Phase as a causal interpretation of cumulative impacts, complementary to the effects analyzed via the CIAP's use of weighted summations. Use of the algorithm is demonstrated with a hypothetical project cluster in the Salmon River Basin (Idaho).

ESA Planning and Environmental Services. 1985. Upper San Joaquin Basin cumulative impact study for hydroelectric developments. Prepared for Division of Water Rights, State Water Resources Control Board, California. v.p.

Abstract (from the Summary). Cumulative impacts identified in the previous sections of this text are summarized for each subarea. The significance of each cumulative impact is also assessed using the approaches outlined. A discussion of significant impacts and mitigative strategies is provided for each target resource.

Over the last century, various regulatory authorities have adopted requirements for specific mitigations as part of hydroelectric licensing agreements in the Upper San Joaquin Basin. Bodies such as SWRCB (State Water Resources Control Board), FERC (Federal Energy Regulatory Commission), USFS (United States Forest Service), and CDFG (California Department of Fish and Game) have required such mitigation measures as minimum fish flow releases, construction of recreation sites, meadow rehabilitation, and sediment and erosion control measures, for example. These mitigations have either addressed specific impacts or have foreseen opportunities (such as recreation) associated with hydro development. Comprehensive mitigation programs, however, are a recent phenomenon. Developments of sixty years ago have had impacts on habitat and timberland, for example, that have not been dealt with because environmental assessment and mitigation were not required. Further, where cumulative impacts are evident, singular mitigation measures meant to address component impacts have not been sufficient. Cumulative impacts, by nature, entail a wide range of resource management influences. These are often well beyond the control of hydro developments which may have contributed to but not been the sole cause of a cumulative impact.

In this report, various current mitigation approaches have been reviewed, particularly those associated with hydro projects. In this section, we consider the sufficiency of those approaches in dealing with cumulative impacts. As well, we examine some of the larger resource management strategies required for long-term protection of the Basin.

Estevez, E.D. 1986. Assessment and policy approaches to managing cumulative impacts in wetlands. Pages 209-212 in J.A. Kusler and P. Riexinger, eds. Proceedings of the national wetland assessment symposium. ASWM Tech. Rep. 1. Association of State Wetland Managers, Chester, VT.

Addition. "The purpose of this paper is to review two techniques for establishing acceptable levels of impact by assessment approaches and one method for determining acceptable levels of cumulative impact without the benefit of a well-developed assessment methodology." One technique for defining development thresholds described by the author is research in natural undeveloped areas so that the structure and function of wetlands can be determined. The need for this research and its drawbacks are discussed. The second assessment approach depends on an active program of project monitoring where development pressures are not intense. The advantages and disadvantages of this approach are discussed. A brief description of "cumulative impact management by means that circumvent altogether the need for setting goals on a case-by-case basis" concludes the paper.

Estevez, E.D., J. Miller, J. Morris, and R. Hamman, eds. 1986. Conference proceedings: managing cumulative effects in Florida wetlands. New College Environmental Studies Program Publ. No. 38. Omnipress, Madison, WI. 326 pp.

Addition. The conference was held to begin the process of developing a workable rule by which the Florida Department of Natural Resources could implement the statute that directs it to consider cumulative effects in the development of wetlands management plans. A framework for the Florida case studies is provided as well as definitions and key concepts involved in cumulative impact analyses. Freshwater and estuarine case studies are discussed. Legal issues in Florida, history and rules, the results of six workshops convened to solve specific problems, and a rapporteur's report are also presented. (An executive summary of the conference was printed under separate cover: New College Environmental Studies Program Publ. No. 37.)

[See also: Ankersen; Barile; Brown; Canter; Gluckman; Kushlan; Neal; Witmer.]

Fairfax, S.K. 1981. A brief, incomplete, and heuristic guide to thinking about legal and institutional aspects of regulating cumulative effects of silvicultural practices on fragile watersheds. Pages 79-93 in R.B. Standiford and S.I. Ramacher, eds. Cumulative effects of forest management on California watersheds. Univ. Cal. Agri. Sci. Spec. Publ. 3268. Berkeley.

Addition. Legal and institutional constraints to solving problems in watersheds caused by silvicultural activities include the riparian and prior appropriation water doctrine, and the cultural, social, and legal principles that encourage private landowners to use their property to maximum economic advantage. These barriers make the use of legal tools to control cumulative effects inefficient and potentially destructive. Burden of proof, antitrust, and proprietary information also complicate and constrict the applicability of legal solutions. The author discusses why these barriers make our society ill-equipped to manage resources on a watershed basis. The author then discusses what authority exists for dealing with cumulative effects and what priorities and criteria should be used in deciding how to apply, expand, or amend existing programs to control cumulative effects. Three scenarios for regulating cumulative effects are provided: (1) establishment of a market mechanism for limiting watercourse disruption, (2) a comprehensive planning approach that focuses on long-term cooperative efforts, and (3) an emphasis on timber harvesting plans.

Feldman, M.D. 1988. National Wildlife Federation v. FERC and Washington State Department of Fisheries v. FERC: Federal Energy Regulatory Commission ignores Ninth Circuit rebuke on hydropower permitting. Ecology Law Quarterly 15:319-360.

Abstract (from the Conclusion). In *National Wildlife Federation* and *Department of Fisheries*, several intervening groups attempted to improve FERC's evaluation of the potential cumulative environmental impacts of multiple hydroelectric developments in the Salmon and Snohomish River Basins. These groups asked the court to find that, under the Federal Power Act, FERC had a duty to prepare a comprehensive plan for these river basins prior to issuing preliminary permits and to require permittees to gather the data needed to assess cumulative impacts. Although the Ninth Circuit did not grant all of the intervenors' requests, the court did remand the preliminary permit decisions to the Commission for a more detailed consideration and evaluation of the merits of the intervenors' proposals.

Despite the Ninth Circuit's criticism of FERC's decisions and the wealth of evidence presented to the agency supporting the intervenors' proposals for cumulative impact assessment, FERC's later preliminary permit decisions in these river basins reveal only the smallest incremental change in the Commission's evaluation of the requests for coordinated review and cumulative impact analysis. FERC's refusal to evaluate these requests carefully is but one example of the Commission's historical failure to obtain, consider, and include sufficient environmental information in its hydropower decisionmaking. FERC's continued refusal to evaluate any of the intervening groups' requests, even after the Ninth Circuit's rebuke, also illustrates the limited potential for judicial review to improve the Commission's preliminary permit decisionmaking.

FERC's history of ignoring new environmental policy demands suggests that, in addition to litigation, explicit statutory reforms are needed to improve the Commission's evaluation of environmental information. For FERC's preliminary permit decisionmaking, the legislative reforms suggested in this Note include specific requirements that FERC engage in comprehensive planning and that the Commission be more responsive to the determinations of state and Federal agencies charged with protecting environmental values. These reforms are necessary to improve FERC's hydropower decisionmaking so that it more closely conforms with congressional intent, judicial interpretation, and the public interest in well-planned hydropower development and in conservation of natural river values.

Ferraro, P., and P. Nazaryk. 1983. Assessment of the cumulative environmental impacts of energy development in northwestern Colorado. Colorado Department of Health and U.S. Environmental Protection Agency, Region VIII. 51 pp.

Abstract. This study examines the direct and secondary impacts of energy development on land, air quality, water quality, solid and hazardous waste disposal, and noise in the region. The study is meant as a general overview of these impacts. It is impossible to actually predict the environmental impact of oil shale development with any certainty because oil shale pollution control technologies have never been tested on a commercial level. However, from work based on pilot projects and existing information, some tentative projections can be made. Although the focus of this study is on the operation phase of these energy operations, the study also attempts to address concerns that may arise during the construction and post-operative phases. One major assumption made throughout the report is that existing State and Federal environmental statutes and regulations will not be relaxed. Major revisions to these laws could lead to considerably more serious consequences than those actually projected in this study. This study also assumes that all energy projects in the region will comply, either voluntarily or through various State and Federal enforcement mechanisms, with these laws and permit requirements. Forced compliance of environmental laws and regulations could be costly both to Colorado and U.S. taxpayers.

The report does not address the possibility that there will be a "crash program" to develop oil shale. It also does not consider the economic costs of compliance with current environmental standards. It is conceivable that compliance could be so costly that industry will attempt to relax environmental standards. These two concerns--a crash program and the relaxation of environmental standards--have been a longstanding concern to many citizens and State and local officials in Colorado.

Addition. Production scenarios for oil shale, coal, powerplants, coal gasification, oil, gas, and uranium, as well as population projections, were developed for the year 2000. Baseline data provided a summary in the form of maps for stream classification, environmentally sensitive areas, occupied ranges of threatened and endangered species, and areas potentially sensitive to acid deposition. Other baseline data summarized were municipal waste volume, capacity of wastewater treatment facilities, population by county, and stream segments where water pollutant concentrations periodically exceed recommended concentrations. Projections of air emissions, potential pH of lakes in Flat Tops Wilderness area, area of spent shale disposal piles after 30 years of operation, municipal waste volume, and municipal water consumption are tabulated.

Gale, J.A., and D.A. Adams. 1984. Cumulative impacts of peat mining. Office of Coastal Zone Management, National Oceanic and Atmospheric Administration and North Carolina Energy Impact Program, Raleigh. Coastal Energy Impact Program Rep. No. 40.

Abstract. Three alternative 20-year peat mining development scenarios were constructed for Hyde, Tyrrell, and Washington Counties, North Carolina, with probable cumulative environmental and economic impacts on: agriculture; forest products; fish; wildlife; recreation; surface water runoff; nutrient, trace element, coliform bacteria and pesticide yields; groundwater; land use conversion; air quality; solid waste; occurrence of fire; and local economics. The most critical potential cumulative impacts were determined to be impacts on estuarine systems, wildlife, and local economies.

Garcia, J., L. Loehr, K. Richter, G. Ahlborn, and F. Westerlund. 1983. Energy related use conflicts for the Columbia River estuary. U.S. Fish Wildl. Rep. No. FWS/OBS-82/60. 447 pp.

Abstract. High, medium, and low probabilities of energy-related development are projected for the Columbia River Estuary to river mile 93. Projections for 5-, 15-, and 25-year planning horizons are aggregated, mapped, and described. The direct and indirect effects of projected energy-related development upon fish and wildlife in estuarine and riverine systems are summarized. Habitats affected by construction are identified, and operations of energy facility components causing impacts are characterized. Ecosystem models are developed for riverine, estuarine, channel, sandflat, mudflat, emergent vegetation, and riparian habitats to determine biological significance and pathways of projected impacts. Species accounts are furnished for 13 species and species groups that are of special concern. Cumulative impacts are integrated and described on a site-specific basis. Policymaking, planning, and regulatory processes relevant to the control of energy-related impacts in the Columbia River Estuary and lower river are outlined. Management and mitigation measures are discussed both for species of concern and for the types of energy facilities expected to be developed.

Geppert, R.R., C.W. Lorenz, and A.G. Larson. 1984. Cumulative effects of forest practices on the environment: a state of the knowledge. Prepared for the Washington Forest Practices Board, Olympia. 208 pp.

Addition. This literature review was to derive a broad, yet useful, definition of "cumulative effects"; develop a first approximation of the nature, source, and extent of cumulative effects of forest practices; and provide direction for future study of cumulative effects. Information from the literature review and interviews was used to determine the effects on the environment of the most common forest practices. Conclusions are presented about the potential of specific forest practices causing cumulative effects and the steps necessary to control cumulative effects.

Glanz, M.H., and G.A. McKay. 1986. Cumulative atmospheric impact assessment. Pages 131-140 in Canadian Environmental Assessment Research Council and United States National Research Council. Cumulative environmental effects: a binational perspective. Minister of Supply and Services Canada.

Addition. Three major atmospheric concerns discussed by the authors are acid rain, the increased concentration of atmospheric carbon dioxide, and the projected depletion of stratospheric ozone. The authors focus attention on five questions: (1) Has cumulative impact assessment been neglected? (2) Whose responsibility is cumulative impact assessment? (3) Where is the best place to control the problems under consideration? (4) Do technologies exist to reduce future pollution of the atmosphere to acceptable levels? and (5) Should we focus on integrated management of these disparate "pollutants" rather than on cumulative impact assessment? The issue concerning who should pay for the impacts and their mitigation is discussed.

Gluckman, D. 1986. The history behind the legislative history of the cumulative effects of wetlands destruction. Pages 229-234 _in_ E.D. Estevez, J. Miller, J. Morris, and R. Hamman, eds. Proceedings of the conference: managing cumulative effects in Florida wetlands. New College Environmental Studies Program Publ. No. 38. Omnipress, Madison, WI.

Abstract. This paper presents an environmental lobbyist's view of the recent development of legislation dealing with piecemeal destruction of wetland starting with the 1982 and 1983 sessions of the Florida Legislature and culminating with passage of the Section 403.919 F.S. (the Warren S. Henderson Wetland Protection Act of 1984). It summarizes the development of problems remaining since the passage of earlier dredge and fill rules, and it includes observations on the Senate Advisory Committee on Wetlands, the 1984 legislative strategy of the Department of Environmental Regulation, and the evolution of the concept of "equitable distribution." The paper focuses on legislative resistance to the term "cumulative impacts" and the more favorable response that welcomed the term "equitable distribution."

Gosselink, J.G., and L.C. Lee. 1986. Cumulative impact assessment principles. Center for Wetland Resources Publ. LSU-CEI-86-08. Louisiana State University, Baton Rouge. 24 pp.

Abstract. At three recent national workshops on bottomland hardwood forests, sponsored by the U.S. Environmental Protection Agency, the difficulty of regulatory control of cumulative impacts was a major issue. This paper summarized an approach and methodology to cumulative impact assessment and regulation, based on ideas generated in the workshops. Current regulatory procedures focusing on site-specific permit applications cannot deal effectively with cumulative incremental degradation of the environment, which is a landscape level phenomenon. Therefore, we recommend an approach that makes use of ecological principles arising from island biogeographic theory as applied to nature preserves. For bottomland hardwood forests this means conserving large forest patches, continuity of patches, and contiguity of bottomland forest with adjacent streams. This can be accomplished only in the context of preplanning and goal-setting within large landscape units (for example watersheds). Some of the major problems of this approach were discussed, and a general plan for cumulative impact management was outlined.

Gosselink, J.G., and L.C. Lee. 1987. Cumulative impact assessment in bottomland hardwood forests. Center for Wetland Resources Publ. LSU-CEI-86-09. Louisiana State University, Baton Rouge. 113 pp.

Abstract. The regulation of cumulative impacts raises a number of issues that are not addressed by the traditional site-specific permit evaluation. For example, because the spatial scale of cumulative impacts is large relative to most individual permit request sites, (a) ecological complexity is dramatically increased, (b) spatial and conceptual boundaries are unclear, and (c) ecological processes that depend on large landscape patterns are difficult to conserve. From a policy standpoint the issue is plagued by fragmented jurisdiction, a need to set goals within which individual permits can be evaluated, the need to maintain regional flexibility, and the imperative to develop a way of maintaining and updating records. Many of the scientific/technical questions of resource conservation have previously been addressed in the context of island biogeography as applied to nature reserves, and the extensive literature on this subject is summarized in this report.

We describe a methodology for cumulative impact assessment and management in bottomland hardwood wetlands that uses the landscape approach of island biogeography. Goals for this approach are to conserve unique bottomland forest functions (water-dependent terrestrial and wetland-dependent aquatic organisms, subsidized production, water quality, and flood water desynchronization) and to conserve landscape pattern (large blocks of bottomland/upland forest appropriately interspersed with smaller tracts, continuity among forest patches, and contiguity between bottomland forest and stream, and between bottomland and upland forest). Finally we provide suggestions for the organization of a cumulative impact assessment, the participants, goal-setting, and the subsequent management of individual permit requests.

Gosselink, J.G., and L.C. Lee. 1988. Cumulative impact assessment principles. Pages 196-203 _in_ J.A. Kusler, M.L. Quammen, and G. Brooks, eds. Proceedings of the national wetland symposium: mitigation of impacts and losses. ASWM Tech. Rep. 3. Association of State Wetland Managers, Chester, VT.

Abstract (from the Introduction). In the last several years a growing recognition of environmental degradation resulting from cumulative impacts has prompted a number of workshops, symposia, and review articles (CEARC et al. 1986; Horak et al. 1983a,b; Roelle et al. 1985; Stakhiv, undated). Most who have considered the issues involved agree that cumulative impacts raise problems that cannot be solved by current methods of dealing with permit applications. For example, Horak et al. (1983b) contrasted the emphasis of established procedures for impact assessment with the emphasis required for cumulative impacts. Traditional procedures are species oriented, assume linear, causal relationships, are focused on individual or segmented processes and sites, and tend to base decisions on a static "snapshot" of the site in its present condition. In contrast, cumulative impact assessment requires a community or landscape orientation in which processes are highly interactive and often nonlinear. The cumulative impact viewpoint must be holistic and integrative, evaluating the impacts within an evolving, dynamic context.

With this daunting contrast in approaches it is no wonder that, although much has been said about the importance of cumulative impact assessment, there have been few successful attempts to deal with it within a regulatory framework. Building on ideas generated in three workshops sponsored by the U.S. Environmental Protection Agency (EPA) on bottomland hardwood forests (Brinson et al. 1985; Gosselink et al. 1986; Lee et al. 1986) we have outlined a procedure for cumulative impact assessment (Gosselink and Lee 1986) that we believe incorporates many of the elements required for successful management of cumulative impacts. Although this procedure was specifically drafted for bottomland hardwood forest wetlands we think the approach is sufficiently general to be applicable to other kinds of wetlands, although the specifics of the methodology would have to be modified. In this paper we discuss and illustrate the approach. We assume that the values to humans of bottomland forests are recognized, and that the reader is convinced that cumulative impacts are occurring and are detrimental. Our focus is on what to do about them.

Granholm, S.L., E. Gerstler, R.R. Everitt, D.P. Bernard, and E.C. Vlachos. 1987. Issues, methods, and institutional processes for assessing cumulative biological impacts. Prepared for Pacific Gas and Electric Company, San Ramon, CA. v.p.

Abstract (from the Executive Summary). This project was designed to provide Pacific Gas and Electric Company (PG and E) with a better understanding of the complex issues surrounding cumulative impacts to biological resources and to review pertinent methods and institutional processes for cumulative impact assessment (CIA). PG and E needs this information: (1) to evaluate and provide this information for CIA's that are conducted by regulatory agencies and involve PG and E projects, and (2) to conduct its own CIA's.

Of the eight types of impact assessment methods described, only five were considered useful for CIA; network, mapping and overlays, modeling, evaluative, and adaptive. Ad hoc, checklist, and matrix methods can be useful, however, for organizing information prior to applying other methods.

More than 90 methods were screened, and 12 of the most promising ones were selected for detailed description and evaluation. The evaluation was based on 11 criteria that addressed how well each method defines the cumulative impact problem, assesses cumulative impacts, and obtains and communicates the needed information. Based on this review the authors arrived at the following conclusions: (1) there is no single method that completely satisfies our evaluation criteria, (2) most of the evaluated methods are good at describing or defining the cumulative impact problem, (3) the performance of these methods in assessing cumulative impacts is likely to be poor, (4) most of the methods have had limited application in a regulatory context, and their application is likely to be very costly, and (5) most methods do not identify specific roles for the proponent or other interested parties in the assessment. Several important questions that have not been adequately addressed by existing institutional processes were discussed: (1) How should the costs and level of effort of a CIA be determined and apportioned among proponents? (2) How should responsibilities for mitigation be apportioned? (3) How can interagency coordination be improved to handle CIA's that involve different types of projects and/or cross agency jurisdictions? (4) When in the project review process should a CIA take place? and (5) How should an agency or proponent select appropriate methods and development scenarios for a particular assessment?

Harris, L.D. 1988. The nature of cumulative impacts on biotic diversity of wetland vertebrates. Environ. Manage. 12:675-693.

Abstract. There is no longer any doubt that cumulative impacts have important effects on wetland vertebrates. Interactions of species diversity and community structure produce a complex pattern in which environmental impacts

can play a highly significant role. Various examples show how wetlands maintain the biotic diversity within and among vertebrate populations, and some of the ways that environmental perturbations can interact to reduce this diversity.

The trophic and habitat pyramids are useful organizing concepts. Habitat fragmentation can have severe effects at all levels, reducing the usable range of the larger habitat generalists while threatening the genetic integrity of small, isolated populations. The complexity of trophic interactions, and the propensity, or necessity, of vertebrates to switch from one food source to another--something we know little about--makes using food chain support as a variable for predicting environmental impacts very questionable. Historical instances illustrate the effects of the accumulation of impacts on vertebrates. At present it is nearly impossible to predict the result of three or more different kinds of perturbations, although long-range effects can be observed. One case in point is waterfowl; while their ingestion of lead shot, harvesting by hunters during migration, and loss of habitat have caused waterfowl populations to decline, the proportional responsibility of these factors has not been determined.

Further examples show multiplicative effects of similar actions, effects with long time lags, diffuse processes in the landscape that may have concentrated effects on a component subsystem, and a variety of other interactions of increasing complexity. Not only is more information needed at all levels, but also impacts must be assessed on a landscape or regional scale to produce informed management decisions. I conclude that a system of replicate wetland reserves that are allowed to interact naturally with the surrounding landscape will be more effective in preserving biotic diversity than isolated sanctuaries.

Hemond, H.F., and J. Benoit. 1988. Cumulative impacts on water quality functions of wetlands. Environ. Manage. 12:639-653.

Abstract. The total effect of cumulative impacts on the water quality functions of wetlands cannot be predicted from the sum of the effects each individual impact would have by itself. The wetland is not a simple filter; it embodies chemical, physical, and biotic processes that can detain, transform, release, or produce a wide variety of substances. Because wetland water quality functions result from the operation of many individual, distinct, and quite dissimilar mechanisms, it is necessary to consider the nature of each individual process.

Sound knowledge of the various wetland processes is needed to make guided judgments about the probable effects of a given suite of impacts. Consideration of these processes suggests that many common wetland alterations probably do entail cumulative impact. In addition to traditional assessment methods, the wetland manager may need to obtain appropriate field measurements of water quality-related parameters at specific sites; such data can aid in predicting the effects of cumulative impact or assessing the results of past wetland management.

Hirsch, A. 1988. Regulatory context for cumulative impact research. Environ. Manage. 12:715-723.

Abstract. Wetlands protection has become a topic of increased public attention and support, and regulation of wetlands loss under Section 404 of the Clean Water Act has received high priority within the U.S. Environmental Protection Agency (EPA). Despite this, the nation is continuing to experience serious wetlands losses. This situation reflects the contentious nature of wetlands protection; it involves fundamental conflicts between environmental and development interests. Better information is needed to support regulatory decisionmaking, including information on cumulative impacts. Currently, consideration of cumulative impacts, although required by various Federal regulations, is limited. One reason is that most regulatory decisions are made on a permit-specific, site-specific basis, whereas cumulative impacts must be assessed on a broader, regional scale. In addition, scientific information and methods necessary to support cumulative impact assessment have been lacking. An anticipatory, planning-oriented framework to complement the existing site-specific permit review program is needed to support more effective consideration of cumulative impacts; such an effort is beginning to emerge. In addition, EPA is supporting research to provide better information on cumulative effects. It is recommended that the EPA program place initial emphasis on synthesis and analysis of existing information, on maximizing its use in decisionmaking, and on information transfer. Recommended approaches include correlation of historic wetlands losses with loss of wetlands function and values, regional case studies, and development of indices of cumulative impact for use in permit review.

Horak, G.C. 1986. Cumulative impacts of rapid urbanization on winter avian diversity in northeastern Colorado. Ph.D. Dissertation. Colorado State University, Fort Collins. 135 pp.

Abstract. The cumulative impact of rapid urbanization in Fort Collins has possibly increased winter bird species richness and maintained bird diversity between 1948 and 1984. A greater number of species has resulted than would normally occur in the natural semi-arid environment. Apparently as the 'forest peninsula' of Fort Collins has increased the number of bird species has increased. This built environment provides an environment that is more diverse than the original environment. Key elements of the built environment are water, energy, variety and structure of vegetation, and bird feeders. Bird species respond to the altered environment by colonizing from surrounding habitats as well as from range extensions. A limited analysis of data for selective northern Colorado cities supports these findings. Human activity in northern Colorado has apparently increased the number of niches in the environment resulting in an increase in winter bird species richness and diversity. A key to predicting the effect of urbanization on bird species richness seems to be the expected change in structural vegetation habitat diversity. Eight recommendations are offered to local governments to maintain or possibly increase bird species richness and diversity.

Horak, G.C., and E.C. Vlachos. 1982. Cumulative impacts and wildlife. Pages 7-13 in R.D. Comer, J.M. Merino, J.W. Monarch, C. Pustmueller, M. Stalmaster, R. Stoecker, J. Todd, and W. Wright, eds. Issues and technology in the management of impacted western wildlife. Tech. Publ. No. 14, Thorne Ecological Institute, Boulder, CO.

Abstract. This paper presents a description of the issue of cumulative impacts, discusses responses to the issue, presents theoretical premises of the issue, and offers recommendations. Fish and wildlife populations and habitat may be affected by many projects of the same type, a project's inducement of other types of activity, or the combined effects of two or more actions on the various components of habitat and wildlife species themselves. Many responses to the cumulative impact issue have resulted from environmental analyses required by the National Environmental Policy Act. The prevailing methodological approach with regard to cumulative impacts is based on determining thresholds. Cumulative impacts are defined as the total, interactive impacts over time, i.e., the sum incremental, synergistic effects on fish and wildlife populations and habitats caused by all current and future actions over time and space. Recommendations are offered in the areas of education and training, research, data bases, and institutions.

Horak, G.C., E.C. Vlachos, and E.W. Cline. 1983a. Fish and wildlife and cumulative impacts: is there a problem? Prepared for the U.S. Fish and Wildlife Service, Eastern Energy and Land Use Team, Kearneysville, WV. Contract No. 14-16-0009-81-058. 24 pp.

Addition. This document is one of three prepared to identify and summarize the state-of-the-art of biological assessment and monitoring of cumulative effects of development on fish and wildlife populations and habitat. It was developed primarily for policymakers and the public. The emphasis of the report is a nontechnical discussion of the cumulative impact issue. Three cases are used to exemplify present assessment approaches and the projected response in 2020 as well as to provide recommendations to help the field biologist. These cases also demonstrate the need for additional research, the development of better data bases, and institutional and decisionmaker changes to help the cumulative impact assessment process.

Horak, G.C., E.C. Vlachos, and E.W. Cline. 1983b. Methodological guidance for assessing cumulative impacts on fish and wildlife. Prepared for U.S. Fish and Wildlife Service, Eastern Energy and Land Use Team, Kearneysville, WV. Contract No. 14-16-0009-81-058. 99 pp.

Addition. This document is one of three prepared to identify and summarize the state-of-the-art of biological assessment and monitoring of cumulative effects of development on fish and wildlife populations and habitats. It provides interim guidance for the field biologist and focuses on available methods that have potential usefulness in assessing cumulative impacts. The document is concerned with a delineation of questions and concepts associated with the search for cumulative impacts, a state-of-the-art summary of relevant

methodologies, recommendations of the best available methodologies, and some broad guidance for performing a cumulative impact assessment.

Hrycak, P. 1978. Cumulative effects of carbon dioxide discharges into atmosphere. Pages 154-157 in Proceedings of the 24th annual technical meeting of the Institute of Environmental Sciences. Combined environments: technology interrelations. April 18-20, 1978, Fort Worth, TX. Institute of Environmental Sciences, Mt. Prospect, IL.

Abstract. There exists a substantial gap between the total mass of atmospheric CO_2 discharges, mainly as the end result of combustion processes, and the CO_2 fraction that remains airborne. The rate of increase of airborne CO_2 appears to lag the rate of increase in fossil fuel consumption, the main source of CO_2 today. The buffering action of the oceans, their ability to absorb large quantities of CO_2, to hold them in suspension, and to precipitate the excess carbon in the form of $CaCO_3$, for example, are given as the most likely explanation for the world-wide mechanism of the airborne carbon regulation. Consequently, there is little likelihood of drastic changes in the atmospheric CO_2 content in the near future. An analogy is shown with a similar mechanism that maintains the oxygen content of the atmosphere constant.

Husky, L. 1979. Statewide impacts of OCS petroleum development in Alaska. Analysis of the cumulative impacts. Western Gulf of Alaska impact analysis. Tech. Memo. No. 39. Contract No. AA 550-CT6-61, University of Alaska, Arctic Environmental Information, Anchorage. Spec. Rep. No. 1. Alaska OCS Socioeconomic Studies Program. v.p.

Abstract. The United States Department of the Interior was designated by the Outer Continental Shelf (OCS) Lands Act of 1953 to carry out the majority of the Act's provisions for administering the mineral leasing and development of offshore areas of the United States under Federal jurisdiction. Within the Department, the Bureau of Land Management (BLM) has the responsibility to meet requirements of the National Environmental Policy Act of 1969 (NEPA) as well as other legislation and regulations dealing with the effects of offshore development. In Alaska, unique cultural differences and climatic conditions create a need for developing additional socioeconomic and environmental information to improve OCS decisionmaking at all governmental levels. In fulfillment of its Federal responsibilities and with an awareness of these additional information needs, the BLM has initiated several investigative programs, one of which is the Alaska OCS Socioeconomic Studies Program (SESP).

The Alaska OCS Socioeconomic Studies Program is a multi-year research effort that attempts to predict and evaluate the effects of Alaska OCS Petroleum Development upon the physical, social, and economic environments within the State. The overall methodology is divided into three broad research components. The first component identifies an alternative set of assumptions regarding the location, nature, and timing of future petroleum events and related activities. In this component, the program takes into account the particular needs of the petroleum industry and projects the human, technological, economic, and environmental offshore and onshore development requirements of the regional petroleum industry. The second component focuses on data gathering that identifies those quantifiable and qualifiable facts by which OCS-induced changes can be assessed. The critical community and regional components are identified and evaluated. Current endogenous and exogenous sources of change and functional organization among different sectors of community and regional life are analyzed. Susceptible community relationships, values, activities, and processes also are included. The third research component focuses on an evaluation of the changes that could occur due to the potential oil and gas development. Impact evaluation concentrates on an analysis of the impacts at the statewide, regional, and local levels.

INTASA, Inc. 1981. National hydroelectric power resources study: environmental assessment. Prepared for U.S. Army Corps of Engineers, Institute for Water Resources, Ft. Belvoir, VA. Contract No. DACW72-80-C-0002. v.p.

Addition. The objectives of this report were to: (1) identify generic environmental impacts, (2) estimate future development, (3) assess the effectiveness of environmental legislation and planning procedures associated with hydropower development, and (4) identify actions that could mitigate expected environmental impacts associated with future hydropower development. Cumulative impacts were a special environmental problem identified during the study. The report provides a six-step procedure for assessing the regional cumulative impacts of hydropower development and uses simple impact indices to evaluate and compare regional differences in hydropower development. These indices require little new data, are easily calculated, and provide a relative comparison of resources to developed hydropower potential between regions. The methodology allows for participation of resource agencies but does not explicitly provide a procedure to prevent the effects of hydropower development. Using this method, INTASA, Inc. determined that cumulative impacts have permanently and severely reduced the anadromous fishery in the Columbia River basin.

Johnston, C.A., N.E. Detenbeck, J.P. Bonde, and G.J. Niemi. 1988. Geographic information systems for cumulative impact assessment. J. Photogramm. Eng. Remote Sensing 54:1609-1615.

Abstract. Geographic Information Systems (GIS) are a valuable tool for assessing cumulative environmental impact, the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions. GIS can be used to quantify rates of regional resource loss by comparing data layers representing different years. GIS can also be used to develop empirical relationships between resource loss and environmental degradation. A cumulative impact evaluation method involving aerial photointerpretation, multivariate statistical analysis, and GIS techniques was developed and used to relate past and present wetland abundance with stream water quality in the Minneapolis-St. Paul metropolitan area. The results demonstrate the importance of wetland position in the watershed to water quality, a relationship which would have been difficult to detect without the benefit of GIS assisted analysis.

Klock, G.O. 1985. Modeling the cumulative effects of forest practices on downstream aquatic ecosystems. J. Soil Water Conser. 40:237-241.

Abstract. Forest land managers are concerned about the potential cumulative effects of multiple management activities, over time and space, within a watershed on downstream aquatic ecosystems. To determine a watershed's hydrologic condition, a Watershed Cumulative Effects Analysis (KWCEA) model was developed. The model uses key watershed parameters affecting streamwater quality and quantity. Its index value implies relative, cumulative-effect, risk-rating levels for past, current, and future forest management practices as well as worst-case conditions. The model is particularly useful for evaluating the potential downstream impact of all forest practice options within a watershed. Output from the KWCEA model can also be used to coordinate the schedule of forest practices among several land ownerships within a watershed.

Klopatek, J.M. 1988. Some thoughts on using a landscape framework to address cumulative impacts on wetland food chain support. Environ. Manage. 12:703-711.

Abstract. Problems of using food chain support as a functional attribute of a wetland are discussed. It is suggested that primary production may not be the metric that best evaluates food chain support. Environmental constructs of the wetland and resultant habitat variables appear to yield more information on life-support functions. A landscape-oriented approach is derived to separate (hierarchically) the wetlands into ecological regions and landscape elements. This classification scheme allows for predetermination of environmental constraints and the possible natural limits of wetland food chain support. It is proposed that models derived from spatial location theory be used to determine the movement of animals from wetland patches experiencing impacts on food chain support. Patch size, distance between patches, habitat diversity, and environmental constraints are incorporated in these models.

Kushlan, J.A. 1986. The Everglades: management of cumulative ecosystem degradation. Pages 61-82 in E.D. Estevez, J. Miller, J. Morris, and R. Hamman, eds. Proceedings of the conference: managing cumulative effects in Florida wetlands. New College Environmental Studies Program Publ. No. 38. Omnipress, Madison, WI.

Abstract. The Everglades was a 9,300 km^2 hyperseasonal savanna occupying the lower third of the Florida peninsula. Historically, it was characterized by slow, down-gradient marsh flow of surface water and by an annual dry period during which surface water was confined to scattered ponds and deep marshes. Reclamation has reduced the area of the Everglades by 65%, the remnant wetland being compartmentalized into shallow reservoirs (the water conservation areas) and a natural area reserve (Everglades National Park). Other land uses of former Everglades include agriculture and residential development. The seasonal cycle of water level fluctuation is the dominating force determining the functional characteristics of the ecosystem. Indigenous plant and animal populations are adapted to the annual water level cycle, and disruption of this cycle has led to the cumulative functional degradation of the ecosystem and disruption of constituent populations.

Investigation of the relationships of water level fluctuation to the biology of certain sensitive populations, including fishes, alligators, wading birds, and shrimp, has provided an understanding of the system's function and options for the active management of surface water. Knowledge is sufficient to undertake this management provided certain premises are accepted. These include that the loss of wetlands, the compartmentalized zoning of the remaining Everglades, and for the most part the deterioration of system function are irreversible. Furthermore, the remnant Everglades must process more water than it did historically, e.g., the problem of water management with respect to the natural system is the management of too much water. In Everglades National Park, but not necessarily in the water conservation areas, management must be aimed at perpetuating ecosystem processes to conserve distinctive plant and animal populations. Finally, the Everglades must be managed actively rather than by benign neglect. Mechanisms are available for active management that can preserve the Everglades ecosystem and needs of various groups dependent upon this wetland ecosystem. The cumulative loss of ecosystem function can be expected in wetland systems that have suffered reduction in size or alteration of critical ecological processes, such as the cycle of water level fluctuation.

Kusler, J.A., and P. Riexinger, eds. 1986. Proceedings of the national wetland assessment symposium. ASWM Tech. Rep. 1. Association of State Wetland Managers, Chester, VT. 331 pp.

Abstract. These proceedings are designed to serve two objectives: to serve as a source book on "how to do it" on wetland assessment; and to provide a status report on evaluation approaches and possible new directions for improving approaches. The proceedings begin with conclusions and recommendations for strengthening assessment. Chapter 9 examines the assessment of cumulative impacts. The report concludes with a discussion of wetland protection in Maine.

[See also: Dennis; Estevez; Stakhiv; Witmer.]

Leathe, S.A., and M.D. Enk. 1985. Cumulative effects of micro-hydro development on the fisheries of the Swan River drainage, Montana. Volume I: Summary report. Prepared for Bonneville Power Administration, Division of Fish and Wildlife, Portland, OR. Project 82-19. 114 pp.

Addition. This two and one-half year study was designed to develop and apply methods to evaluate the cumulative effects of 20 proposed small hydro projects on the fisheries resources of the Swan River drainage in northwestern Montana. Fish population estimates, habitat analyses, and creel census information were obtained from reaches throughout the drainage to predict the impacts. Bull trout were considered the primary species of concern because of their extensive use of project areas, sensitivity to sedimentation, and importance to lake and river sport fisheries.

Dewatering and sedimentation were the major impacts considered. The impacts were predicted to cause the loss of 2% to 72% of juvenile bull trout populations within individual project drainages; adding the effects of forest roads increased the losses to 11% to 84%, or 1% to 8% of the drainage-wide population. Small hydro development would result in losses constituting 5% and 2% of the cutthroat and brook trout populations, respectively.

The effects of the individual projects were aggregated to predict cumulative impacts of six scenarios of small hydro development. Dewatering of diversion zones accounted for the greatest bull trout losses, which ranged from 14% to 31%, depending on the scenario. Cutthroat were also significantly affected, while the brook trout losses were minimized because they are not abundant in the project areas. Economic losses were evaluated using hedonic travel-cost analysis, willingness-to-pay valuation, and willingness-to-drive valuation. The bull trout fishery was found to be the most valuable.

Leathe, S.A., S. Bartelt, and L.M. Morris. 1985a. Cumulative effects of micro-hydro development on the fisheries of the Swan River drainage, Montana. Volume II: Technical information. Prepared for Bonneville Power Administration, Division of Fish and Wildlife, Portland, OR. Project 82-19. 106 pp.

Addition. This is the data that supports the main report (Leathe and Enk 1985). It consists of tables and graphs of hydrologic, habitat, chemical, and fishery data.

Leathe, S.A., S. Bartelt, and L.M. Morris. 1985b. Cumulative effects of micro-hydro development on the fisheries of the Swan River drainage, Montana. Volume III: Fish and habitat inventory of tributary streams. Prepared for Bonneville Power Administration, Division of Fish and Wildlife, Portland, OR. Project 82-19. 151 pp.

Addition. This volume contains maps and biophysical inventory data gathered on tributary streams in the Swan River drainage. It is a support document for the main report (Leathe and Enk 1985). A reach-by-reach description of each sampled stream is provided, including maps, stream features, and fish populations and spawning use. This information is also tabulated for easy reference.

Leathe, S.A., M.D. Enk, and P.J. Graham. 1985. An evaluation of the potential cumulative bioeconomic impacts of proposed small-scale hydro development on the fisheries of the Swan River drainage, Montana. Pages 377-387 in F.W. Olson, R.G. White, and R.H. Hamre, eds. Proceedings of the symposium on small hydropower and fisheries. American Fisheries Society, Western Division and Bioengineering Section.

Abstract. Cumulative fisheries impacts of small hydro projects proposed for tributary streams in the Swan River Basin of northwestern Montana were investigated. Tributary fish populations consisted primarily of resident brook trout (*Salvelinus fontinalis*), resident west slope cutthroat trout (*Salmo clarki lewisi*), and juvenile bull trout (*Salvelinus confluentus*) from a fluvial population residing in Swan Lake. The effects of total dewatering of project areas and increased stream sedimentation due to small hydro and forest development were predicted. Up to 4%, 18%, and 32% of drainage-wide populations of brook, cutthroat, and bull trout, respectively, could be lost if full development occurred, primarily because of dewatering. Individual stream populations could suffer losses as great as 50% for brook trout, 90% for cutthroat trout, and 84% for bull trout. Based on creel and economic surveys, annual net values were estimated at $788,000 (travel-cost) for the entire Swan River drainage sport fishery and $232,000 (hedonic travel-cost) for the highly-valued migratory bull trout fishery. The estimated value to anglers of a 25% fish loss in the drainage varied from $250,000 (willingness-to-drive) to $2,600,000 (willingness-to-sell).

Lee, L.C., and J.G. Gosselink. 1988. Cumulative impacts on wetlands: linking scientific assessments and regulatory alternatives. Environ. Manage. 12:591-602.

Abstract. This article is an extension and application of Preston and Bedford (1988), especially as relevant to bottomland hardwood (BLH) forests of the southeastern United States. The most important cumulative effects in BLH forests result from incremental forest loss (nibbling) and from synergisms resulting from this nibbling. Present regulatory procedures are ineffective in preventing incremental forest loss because of the focus on permit site evaluation, rather than on large landscapes. Three examples are given to illustrate the need for a landscape focus. This perspective requires pre-planning or goal-setting to establish the desired conditions to be maintained in the regulated landscape unit.

Spatial and temporal scales are of particular concern for landscape impact assessment. Natural drainage basins of about 10^6 ha, as identified in U.S. Geological Survey hydrologic units, appear to be appropriate spatial units: they have fairly natural boundaries, are of sufficient size to support populations of large, wide-ranging mammals, and are compatible with existing maps and databases. Time scales should be sufficiently long to include recovery of wetland ecosystems from human perturbations. In practice, available data sets limit analysis to no longer than 50 yr. Eight indicators of landscape integrity are identified, based on generally available long-term data sets.

Linking technical information concerning cumulative effects on landscapes to the evaluation of cumulative impacts in regulatory programs (i.e., goal-setting) is a serious issue that can benefit from precedents found in the field of epidemiology, and in the establishment of clean air and clean water standards. We suggest that reference data sets must be developed, relating BLH function to structure (forest area). These can be used to set goals for individual watersheds, based on their present conditions and the magnitude and type of perceived development pressures. Thus the crucial steps in establishing a successful program appear to be (1) establish study unit boundaries, (2) assess the condition of study unit landscape integrity, (3) set goals, and (4) consider the impacts of permit proposals with both goals and the existing condition of the study unit landscape in mind.

Lumb, A.M. 1982a. Cumulative impact assessment of surface mining. Pages 145-150 in F. Kilpatrick and D. Matchett, eds. Proceedings of the eastern conference on water and energy: technical and policy issues. American Society of Civil Engineers, New York, NY.

Abstract. The Surface Mining Control and Reclamation Act of 1977 requires the designated regulatory authority of each State to assess the probable cumulative impacts of all anticipated mining upon the hydrology of the area. The Act also states that quantity and quality of water are to be considered as well as seasonal variations in flow. Techniques are developed to assess the probable cumulative impacts and include concepts of a hydrologic-activity profile, an impact matrix, and an impact profile. First an activity profile of cumulative drainage area versus river miles downstream from the surface- mining site is constructed that shows major water uses, flood-prone areas, and stream classifications. From the summary shown by the activity profile, an impact matrix is used as a checklist for the probable importance of the impacts under categories such as water supply, flood-prone areas, water-contact recreation, etc. Based on the categories checked on the impact matrix, a simple, less accurate model or a more comprehensive and accurate one can be used to quantify the impacts. Quantified impacts are then displayed on an impact profile showing the percentage change in a hydrologic characteristic versus distance downstream of the surface-mining site. The simple model for quantification considers only dilution from tributary areas during critical periods, whereas the comprehensive model routes flows and quality of water continuously through the year and considers, in addition to dilution, instream processes such as settling, biological uptake, and chemical reactions.

Lumb, A.M. 1982b. Procedures for assessment of cumulative impacts of surface mining on the hydrologic balance. U.S. Geol. Surv. Open-File Rep. 82-334. 50 pp.

Abstract. The Surface Mining Control and Reclamation Act of 1977 requires the designated regulatory authority of each State to assess the probable cumulative impacts of all anticipated mining upon the hydrology of the area. The Act also states that quantity and quality of water is to be considered as well as seasonal variations in flow.

Techniques were developed to assess the probable cumulative impacts including concepts of a hydrologic activity profile, an impact matrix, and an impact profile. An activity profile of cumulative drainage area versus river miles downstream from the surface-mining site is constructed that shows major water uses, flood-prone areas, and stream classifications. From the summary shown by the activity profile, an impact matrix is used as a checklist for the probable importance of the impacts under categories such as water supply, flood-prone areas, and water-contact recreation. These impacts are quantified either by a simple model or a more comprehensive and accurate one and are displayed on an impact profile showing the percentage change in a hydrologic characteristic versus distance downstream of the surface-mining site. The simple model for quantification considers only dilution from tributary areas during critical periods, whereas the comprehensive model routes flows and quality of water continuously through the year and considers, in addition to dilution, instream processes such as settling, biological uptake, and chemical reactions.

Maryland Department of Natural Resources. 1982. Power plant cumulative environmental impact report. Maryland Dep. Nat. Resour. Power Plant Siting Program Rep. PPSP-CEIR-3. Annapolis, MD. 354 pp.

Addition. This study seeks to evaluate the impacts of all power plants on the environment in Maryland. The power demands and supply in the State are discussed in the first two chapters. The remaining chapters discuss the impacts of power plants on air quality, aquatic life, radioactivity in the environment and in biota, socioeconomics, noise levels, groundwater levels, and solid waste volume. Some effort was made to determine the effects that the entire power system has had in each of these areas, but an assessment of the overall impact was not made. The recommendations deal with the permitting process, the need to determine methods and locations for storage of high level waste, and the need for long-term plans for transmission corridors.

McTaggart-Cowan, I. 1975. Cumulative impact of development of the MacKenzie Estuary/Delta, N.W.T. Pages 71-82 in Conference proceedings December 3-4, 1975 entitled Mackenzie Delta: priorities & alternatives. Canadian Arctic Resources Committee, Ottawa, Ontario.

Abstract (from the Introduction and Summary). This sudden and massive arrival of industrialization into the Mackenzie Delta region cannot help but have important social and environmental consequences. It is important, therefore, to anticipate as many as possible of the changes that could occur, and on this basis to arrive at decisions as to the kinds of development that are to be permitted, the timing of these, and the steps to be taken to direct change in more desirable directions.

The absence of a comprehensive land use plan for the Delta based upon good land capability studies makes wise choice of kinds, modes, and timing of development difficult and unlikely to succeed. The massive and diversified projects that are being discussed include the potential for deterioration for the renewable resources of fish, wildlife, clean water, and unaltered landscape. Many of the potentially harmful effects can be avoided or reduced even with today's technology. The important question remains: With the demonstrated priority for northern development as a primary objective, how serious is the concern for maintaining the perpetual resources? Past performance is not reassuring.

Meehan, R., and P.J. Webber. 1985. Towards an understanding and assessment of the cumulative impacts of Alaskan North Slope oil and gas development. U.S. Environmental Protection Agency under U.S. Department of Energy Interagency Agreement No. DE-A106-84RL10584.

Abstract. This report is part of a U.S. Fish and Wildlife Service project to develop a guidance manual for predicting and evaluating the impacts of proposed oil and gas developments on the Alaskan North Slope. An analysis of potential cumulative impacts is a requirement prior to the development of wet tundra. However, it is an issue that has been inadequately addressed in practice. Several reasons for this are the lack of knowledge of the mechanisms and definitions of cumulative impacts, the lack of methods to predict and detect them, inadequate coordinating and planning between developers, and an insufficiency of guidelines from the appropriate Federal and State agencies. A plea is made to remedy this situation via more research into the nature and occurrence of cumulative impact and via the development of specific stipulations and guidelines for environmental impact analysis. This report documents for the first time that crescive secondary physical impacts, as indicated by increased thermokarst, are occurring at Prudhoe Bay. These impacts can be related to the primary direct impacts of road, pad, and facility construction. This report also documents for the first time that the density of breeding shorebird populations is affected by the density of oil field facilities. The manual will incorporate recommendations about maximum facility density and, should this density be exceeded, the necessary mitigation procedures.

Mentor, J., Jr. 1985. Cumulative impacts and comprehensive planning: a problem of synergism and a policy dilemma. Pages 351-356 in F.W. Olson, R.G. White, and R.H. Hamre, eds. Proceedings of the symposium on small hydropower and fisheries. American Fisheries Society, Western Division and Bioengineering Section.

Abstract. This paper examines present Federal law regarding licensing of hydroelectric projects and concludes that present hydroelectric licensing procedures are inadequate to address the problem that, cumulatively, hydroelectric development could adversely affect natural resources found in many river systems. The paper analyzes and considers refinements to recent administrative proposals to address the cumulative impact of hydroelectric development. Finally, the paper evaluates the need for comprehensive planning as appurtenant to consideration of cumulative impacts and offers possible legislative and administrative solutions to the problems associated with future hydroelectric development on the Nation's river systems.

Addition. The paper specifically discusses the proposal by the Federal Energy Regulatory Commission to use the Cluster Impact Assessment Procedure. It describes what the procedure was designed to do, what steps were included in the process, and why the procedure failed to address the need for comprehensive planning.

Merson, A., and K. Eastman. 1980. Cumulative impact assessment of western energy development: will it happen? University of Colorado Law Review 51:551-586.

Addition. The legal structure of cumulative impact assessment is reviewed, and the authors question whether the cumulative impacts of energy resource development in Colorado will be adequately assessed. The article discusses the regulatory mechanisms developed under NEPA that mandate cumulative impact assessment as well as State and local legal and regulatory mechanisms that emphasize consideration of cumulative impacts. The authors conclude that "the emphasis of the Colorado Joint Review Process is on streamlining numerous federal, state, and local processes and not on an anticipating cumulative or synergistic impacts of forthcoming activities."

National Research Council, Committee on the Applications of Ecological Theory to Environmental Problems. 1986. Ecological knowledge and environmental problem-solving: concepts and case studies. National Academy Press, Washington, DC. 388 pp.

Abstract (from Structure and Audience of the Report). The report is divided into "What we know" (Part I) and "How our knowledge is applied" (Part II). Chapters 1-5 treat a number of categories of ecological knowledge and Chapters 6-10 discuss procedures and kinds of knowledge that are common to most environmental problems. Part II presents studies of 13 specific cases of environmental problem-solving.

Chapter 9 deals with cumulative environmental changes that result from repeated perturbations. There is increasing recognition that some of our most severe environmental problems involve the cumulative effects of many small local actions--individually insignificant, but collectively creating major regional and even global changes. The discussion points out the major issues associated with cumulative effects, which have only recently begun to receive serious consideration, but which present some of the most difficult challenges to decisionmakers.

Chapter 10 deals with procedures for application of ecological knowledge. It begins with a discussion of how ecology can help in conceptualizing a problem and in devising appropriate approaches to its solution. We focus on the design of ecological studies for predicting and managing the effects of manipulations, emphasizing the importance of monitoring projects and decisions to determine their consequences.

Neal, P. 1986. Senators' views of 1984 Wetlands Protection Act managing cumulative effects in Florida wetlands. Pages 223-228 in E.D. Estevez, J. Miller, J. Morris, and R. Hamman, eds. Proceedings of the conference: managing cumulative effects in Florida wetlands. New College Environmental Studies Program Publ. No. 38. Omnipress, Madison, WI.

Abstract. The process leading to enactment of the Warren S. Henderson Wetlands Protection Act of 1984 is a model of public policy formation. After the 1982 elections, there was new support by the media, the public, and the legislative leadership for passing wetlands legislation. Both the House and Senate began focusing attention early in the year by appointing advisory committees, which provided vehicles for negotiation and created the expectation that wetlands legislation would be enacted. Compromise occurred and passage was almost unanimous in both houses.

New York State Energy Research and Development Authority. 1981. Cumulative environmental impacts of coal conversion. Rep. No. ERDA-81-29. Albany, New York. 392 pp.

Addition. The conversion of eight oil-fired power plants to coal and the construction of six new coal-fired power plants by 1994 have been proposed as part of the State Energy Master Plan. This report was prepared to present information and draw conclusions about the potential cumulative environmental impacts associated with implementing this plan. The general conclusions are: (1) the entire plan could be implemented without causing significant adverse cumulative effects, provided that appropriate mitigation measures and coordinated planning take place; (2) the greatest potential for adverse cumulative effects on air quality, water supply, transportation, and waste disposal would be in the New York metropolitan area; and (3) minor impacts of a site-specific nature would occur. Chapters on air quality, extraction of flue gas desulfurization minerals, solid wastes disposal, water quality and supply, transportation, visual and aesthetic considerations, ecological effects, and health and safety detail these findings.

O'Brien, A.L. 1988. Evaluating the cumulative effects of alteration on New England waters. Environ. Manage. 12:627-636.

Abstract. In New England, patterns of glacial deposition strongly influence wetland occurrence and function. Many wetlands are associated with permeable deposits and owe their existence to groundwater discharge. Whether developed on deposits of high or low permeability, wetlands are often associated with streams and appear to play an important role in controlling and modifying streamflow. Evidence is cited showing that some wetlands operate to lessen flood peaks, and may have the seasonal effect of increasing spring discharges and depressing low flows. Wetlands overlying permeable deposits may be associated with important aquifers where they can produce slight modifications in water quality and head distribution within the aquifer. Impacts to wetlands undoubtedly will affect these functions, but the precise nature of the effect is difficult to predict. This is especially true of incremental impacts to wetlands, which may, for example, produce a change in streamflow disproportionate to wetland area in the drainage basin, i.e., a nonlinear effect as defined by Bedford and Preston (1988). Additional research is needed before hydrologic function can be reliably correlated with physical properties of wetlands and landscapes.

A model is proposed to structure future research and explore relationships between hydrologic function and physical properties of wetlands and landscapes. The model considers (1) the nature of the underlying deposits (geologic type), (2) location in the drainage basin (topographic position), (3) relationship to the principal zone of saturation (hydrologic position), and (4) hydrologic character of the organic deposit.

O'Riordan, J. 1986. Cumulative assessments and the freshwater environment. Pages 55-66 *in* Canadian Environmental Assessment Research Council and

United States National Research Council. Cumulative environmental effects: a binational perspective. Minister of Supply and Services Canada.

Addition. This paper considers the management of the accumulation of impacts resulting from a number of individual developments on the environment as well as the analysis of impacts among watersheds in a defined geographical area. Rather than attempting a balance between all competing users of a watershed, it may be more appropriate to serve competing demands among a number of watersheds by designating priority uses on each watershed. This paper emphasizes that the linkages among all natural environmental systems cannot be ignored and that cumulative impacts often cross jurisdictional responsibilities. Four case studies are presented: Fraser River and estuary water quality, Okanagan Valley water quality, hydropower project development on the Fraser-Peace River, and cumulative assessments across watershed boundaries in Canada. The emphasis in these descriptions is on institutional rather than scientific issues. Finally, recommendations concerning information systems and decisionmaking structures within the developing research agenda are provided to strengthen the role of cumulative assessment in environmental management.

Palmer, S.D., and M. Murphy. 1984. Cumulative hydrologic impact assessment: the effects of coal mining on the hydrologic systems of the Raton coal field, north-central New Mexico. New Mexico Bureau of Surface Mining, Mining and Minerals Division, Santa Fe. 192 pp.

Abstract. All present and proposed coal mines are located on tributaries of the Upper Vermejo River. Coal mining in York Canyon started in 1966. Mining in York Canyon can be expected to continue for 20-30 years. Future coal mines will be located on other adjacent tributaries of the Vermejo River. Mines evaluated in this document include the York Canyon Surface and Underground Mines, the Upper York Canyon (Cimarron) Underground Mine and the proposed Ancho Canyon Surface Mine, and Juan Baca Canyon (Rosado) Underground Mine. The Cumulative Impact Area (CIA) Boundaries include the Vermejo and Canadian River drainage basins above the USGS surface water monitoring sites at Hebron, NM, and Dawson, NM. The CIA boundaries are located so that all known and future coal mines are within these boundaries.

This document describes and evaluates baseline water quality of surface and groundwaters, describes the quality of waters that discharge into surface and groundwater systems, describes the quality of waters that have been impacted by mining-related activities, and describes stream-channel geomorphic impact. The quality of surface and groundwaters that enter an adjacent alluvial valley floor are assessed. Evaluation of available data indicates that some impacts to waters are associated with mining-related activities. However, as far as can be determined, these impacts are not of sufficient magnitude to cause "Material Damage" to the hydrologic systems of the region.

Panek, F.M. 1979. Cumulative effects of small modifications to habitat. Fisheries 4(2):11-13.

Addition. This paper describes the concerns that the American Fisheries Society (AFS) has about the potential long-term cumulative effects of small habitat modifications on the fisheries resources of North America. Of particular concern are habitat modifications associated with projects for which an environmental evaluation is not required and therefore not identified and/or regulated by resource management agencies. The impacts of the accumulations of small modifications are described and exemplified with several case histories.

The AFS recommended the following major actions: (1) strongly encourage further research and documentation of these impacts and then develop guidelines for evaluating impacts in each habitat type, (2) emphasize the need for a holistic approach to watershed management, (3) evaluate individual projects on their own merits only within the framework of sound watershed management, (4) administer the control and regulation of small habitat modifications on a local or regional level and make it an important component of land-use planning and watershed management, (5) provide expertise and material that identifies and defines the issues, problems, and potential solutions for minimizing loss of habitat, and (6) develop educational programs (through cooperative efforts of AFS, universities, and resource management agencies) to increase public awareness of the problems, hazards, and implications of loss of aquatic habitat.

Paquet, P.S., and G.W. Witmer. 1985. Cumulative impacts of small hydropower developments: an overview of the issues. Pages 343-345 in F.W. Olson, R.G. White, and R.H. Hamre, eds. Proceedings of the symposium on small hydropower and fisheries. American Fisheries Society, Western Division and Bioengineering Section.

Abstract. Despite legislative and administrative mandates that cumulative impacts be incorporated as an element of environmental impact assessment, governmental agencies and consultants have been slow to develop and use the necessary methods. Part of the problem lies in the definition of cumulative impacts, part lies with methodology difficulties, and part lies in the perceptual horizons of those assessing the impacts. Nonetheless, as land use and energy production expand and intensify, concern with cumulative impacts is increasing. A shift toward cumulative impact assessment of hydroelectric development in the Pacific Northwest serves as a good example. Especially since passage of the Northwest Power Act of 1980, Federal, State, and tribal agencies and advocacy groups all have recognized the need to assess impacts within a regional context.

Peterson, E.B., Y.-H. Chan, N.M. Peterson, G.A. Constable, R.B. Caton, C.S. Davis, R.R. Wallace, and G.A. Yarrington. 1987. Cumulative effects assessment in Canada: an agenda for action and research. Prepared for Canadian Environmental Assessment Research Council. Minister of Supply and Services Canada. Cat. No. En 106-7/1987E. 63 pp.

Abstract (from the Executive Summary). This state-of-the-art review of cumulative effects assessment in Canada, initiated by the Canadian Environmental Assessment Research Council (CEARC), confirmed that cumulative effects are having an increasingly significant impact on the quality of natural and social environments in Canada. Accordingly, it was concluded that CEARC should continue to focus part of its program on cumulative effects assessment.

The many identifiable cumulative effects, when viewed as single cause and effect processes, were grouped into 13 sets of cumulative effects issues that are considered to be of particular significance for Canadians over the next decade or two. They are:

- long-range transport of air pollutants;
- urban air quality and airshed saturation;
- mobilization of persistent or bioaccumulated substances;
- cumulative effects associated with climatic modification;
- occupation of land by manmade features;
- habitat alienation;
- habitat fragmentation;
- losses of soil quality and quantity;
- effects of use of agricultural, silvicultural, and horticultural chemicals;
- reduction of groundwater supplies and groundwater contamination;
- increased sediment, chemical, and thermal loading of freshwater and marine habitats;
- accelerating rates of renewable resource harvesting; and
- long-term containment and disposal of toxic wastes.

There is a surprisingly diverse set of examples in which cumulative effects have been recognized and brought under a system of control and management in Canada. The scientific and institutional factors that promoted a successful approach to the analysis and management of cumulative effects in Canada can be summarized as follows:

- cumulative effects are more readily managed if there are determined efforts to achieve co-operative agreements where there are complex divisions of jurisdictional responsibility;

- cumulative effects have a greater chance of successful management if there are determined efforts to involve interested parties during the development of co-operative regulatory agreements;

- cumulative effects that directly threaten human life result in more successful management approaches than do less threatening or less readily understood cumulative effects; and

- cumulative effects that are a result of well-understood pathways have an increased chance of successful management.

In many cases, the apparent successes are a result of distinctive circumstances that possess no guarantee of effective application to cumulative effects of other forms or in other jurisdictions. Several relationships between complexity of jurisdictional controls and the management of cumulative effects have been well documented and this review concluded that under the appropriate circumstances jurisdictional complexity, by itself, is not a deterrent to effective management of cumulative effects if the will to act is present. It was confirmed that there are well-defined limitations in the degree to which project referrals and project-specific environmental impact assessments can be adapted to manage cumulative effects successfully. Despite this confirmation, the present review did result in recommendations that involve steps within existing environmental impact assessment procedures.

In general, this review confirmed the CEARC hypothesis that current approaches for both scientific analyses and institutional arrangements to manage cumulative effects remain inadequately developed in Canada. To address these weaknesses, cumulative effects management requires action on three fronts, identified in this review as: (1) ecosystem-management links, (2) research-ecosystem links, and (3) research-management links. Recommendations for an action program and a research agenda are presented for each of these fronts.

Phillips Brandt Reddick McDonald and Grefe, Inc. 1978. The cumulative impacts of shorezone development at Lake Tahoe. Prepared for California State Lands Commission, State of Nevada, Tahoe Regional Planning Agency, and U.S. Army Corps of Engineers. v.p.

Addition. The specific purpose of this study was to provide an assessment of the cumulative environmental and socioeconomic impacts of a proliferation of piers, mooring buoys, floating docks, and shoreline protective structures in the nearshore and foreshore zones of Lake Tahoe. To implement information developed from the literature review and interviews, an analysis of littoral dynamics; an inventory of parcels, land use, and shorezone structures; and two surveys of recreational use and shorezone user perceptions were conducted. Gaps in basic data and in the scientific understanding of the data that has been collected limited the extent to which cause-effect relationships could be strictly proven. In numerous cases, the available data has not been sufficient to allow for testing of the hypotheses about impacts presented in the report. The impact assessment model was summarized in the form of four impact matrices to be used for project evaluation, but not quantitative assessment.

The conclusions in the report cover five main areas: physical shoreline stability, water quality, biology, recreation, and economics. It was determined that the local incidence of shoreline erosion and accretion will increase as new, relatively impermeable, structures are built in the shorezone. Conclusions about the physical effects of increased densities of piers could not be drawn. Increased loading of nutrients and other pollutants, turbidity, hydrocarbon discharges, and risk of accidental discharges of petroleum products are expected, leading to incremental degradation of water quality. Maximum protected development is not expected to lead to cumulative lakewide impacts to backshore vegetation, wildlife, fisheries, or aquatic communities. However, the authors recommended a habitat management and monitoring program be developed immediately for marsh habitats. The predominant user groups of the shorezone are likely to be the most negatively affected, and maximum buildout will reduce user enjoyment in some areas of the shorezone. Maximum buildout will lead to minimal economic return. The authors recommend an investigation that implicitly examines potential backshore effects of shorezone development.

Preston, E.M., and B.L. Bedford. 1988. Evaluating cumulative effects on wetland functions: a conceptual overview and generic framework. Environ. Manage. 12:561-564.

Abstract. This article outlines conceptual and methodological issues that must be confronted in developing a sound scientific basis for investigating cumulative effects on freshwater wetlands. We are particularly concerned with: (1) effects expressed at temporal and spatial scales beyond those of the individual disturbance, specific project, or single wetland, that is, effects occurring at the watershed or regional landscape level; and (2) the scientific (technical) component of the overall assessment process. Our aim is to lay the foundation for a research program to develop methods to quantify cumulative effects of wetland loss or degradation on the functioning of interacting systems of wetlands. Toward that goal we: (1) define the concept of cumulative effects in terms that permit scientific investigation of effects; (2) distinguish the scientific component of cumulative impact analysis from other aspects of the assessment process; (3) define critical scientific issues in assessing cumulative effects on wetlands; and (4) set up a hypothetical and generic structure for measuring cumulative effects on the functioning of wetlands as landscape systems.

We provide a generic framework for evaluating cumulative effects on three basic wetland landscape functions: flood storage, water quality, and life support. Critical scientific issues include appropriate delineations of scales, identification of threshold responses, and the influence on different functions of wetland size, shape, and position in the landscape.

The contribution of a particular wetland to landscape function within watersheds or regions will be determined by its intrinsic characteristics, e.g., size, morphometry, type, percent organic matter in the sediments, and hydrologic regime, and by extrinsic factors, i.e., the wetland's context in the landscape mosaic. Any cumulative effects evaluation must take into account the relationship between these intrinsic and extrinsic attributes and overall landscape function. We use the magnitude of exchanges among component wetlands in a watershed or larger landscape as the basis for defining the geographic boundaries of the assessment. The time scales of recovery for processes controlling particular wetland functions determine temporal boundaries. Landscape-level measures are proposed for each function.

Proett, M.A. 1987. Cumulative impacts of hydroelectric development: beyond the cluster impact assessment procedure. Harvard Environmental Law Review 11:77-146.

Abstract (from the Introduction). Evaluating the cumulative effects of many projects presents unique complexities. It requires quantification and addition of impacts, and consideration of development options in light of basin-wide impacts on whole natural populations and resources. Problems have arisen, however, because the first steps of comprehensive impact assessment have entailed consideration of total environmental goals and effects in the same manner as the more immediate development goals and intended effects. This article will examine some of those problems and suggest possible solutions.

A primary problem is the definition of goals. The immediate goal of increased hydropower development is clear--the addition of a renewable power source to the nation's energy supply. The environmental goal is simple only when defined abstractly--the electricity should be generated at the least environmental cost. When defined more particularly, reaching actual development decisions becomes problematic: determining an acceptable environmental cost for a single hydropower plant and calculating how that cost should be compared to the marginal benefit of increased electricity is very difficult. Multiply the difficulty of a single assessment by the need to plan an extensive development scenario, and the complexity approaches the unmanageable. Because of such complexity, decisionmakers may simplify the environmental goal, and never compare it to the goal of electricity production. Thus, the decision to build a project in the first place may be presumed acceptable to further the energy goal, while the environmental goal will only bring about modifications in project design to mitigate any identified environmental degradation.

Raley, C.M., W.A. Hubert, and S.H. Anderson. 1987. Development of a qualitative cumulative effects model to assess external threats to the North Fork Flathead River Basin within Glacier National Park. U.S. Fish Wildl. Serv. NERC-88/19. 39 pp.

Abstract (from the Summary). At least 56 external threats to the ecology of Glacier National Park have been identified. While this is a parkwide situation, park managers have identified the North Fork Basin of the Flathead River as a region that is particularly sensitive to external land use activities.

A problem analysis technique was used to evaluate the cumulative effects of external activities on the resources within the North Fork Basin of Glacier National Park. The technique assembled existing information into a logical format. The result was a cause and effect model from which resource managers can assess the scope of environmental effects of existing and potential activities in the North Fork Basin. The cause and effect analysis was conducted during a 3-day workshop at Glacier National Park. The approach involved defining a problem statement representing the environmental situation in the North Fork Basin, modeling the causes and effects of the problem, and defining management objectives and tasks to prevent or remedy the problem. The attributes of the problem analysis technique are discussed, and recommendations are made on how the models can be used as communication and management tools.

Reed, R.M., J.W. Webb, and G.F. Cada. 1984. Siting energy projects: the need to consider cumulative impacts. Pages 320-328 in Proceedings of facility siting and routing '84 energy and environment. Banff, Alberta.

Addition. A review of environmental impact statements on energy projects found that most analyses of cumulative impacts were written in very general terms, presented few data to support these general conclusions, and appeared to have had little influence on the selection of the environmentally preferred site. The authors discuss four problem areas that must be confronted in scoping the study: defining the geographic area to be considered, identifying activities within the impact area that are relevant and should be considered, developing baseline data on regional resources and project impacts, and preparing a reasonable methodology for evaluating individual and combined project effects.

Rice, R.M. 1981. A perspective on the cumulative effects of logging, streamflow, and sedimentation. Pages 36-46 in R.B. Standiford and S.I. Ramacher, eds. Cumulative effects of forest management on California watersheds. Univ. Cal. Agri. Sci. Spec. Publ. 3268. Berkeley.

Addition. The rain-dominated watersheds of the Coast Forest District in California are used as examples of cumulative effects of logging on watersheds, although most of the effects may be observed in the snow-dominated watersheds of the northern and southern districts. Logging increases runoff, at least temporarily, due to reduced interception losses, reduced transpiration, changed accumulation, and snow melt. Yarding disturbances and burning of slash also increase runoff. The importance of higher peak discharge derives from the accompanying sedimentation, which may or may not occur depending on the availability of sediment. Examples of increased discharge with and without sedimentation are given. Thirty percent of erosion variability was explained by site differences in yarding methods; about 60 percent could not be explained by 13 other variables. Recommended tactics for dealing with cumulative effects of logging include reducing surface and mass erosion, research to increase ability to predict and control individual effects, and dispersing watershed disturbances as greatly as feasible in time and space.

Risser, P.G. 1988. General concepts for measuring cumulative impacts on wetland ecosystems. Environ. Manage. 12:585-590.

Abstract. Because environmental impacts accumulate over space and time, analysis is difficult, and we must incorporate the most recent scientifically defensible information and methods into the process. Methods designed to deal specifically with cumulative impacts include checklists of characteristics or processes, matrices of interactions (rated according to their level of importance) between disturbance activities and environmental conditions, nodal networks or pathways that depict probable effects of disturbances, and dynamic system models. These methods have been tested over the past decade and have proven generally successful.

Landscape perspectives have emerged as especially helpful in analyzing cumulative effects and have focused specific attention on questions of spatial and temporal scale, while leading to recognition of the complexity of ecosystem processes in general. An evaluation of several case studies by the Commission on Life Sciences of the U.S. National Academy of Sciences emphasizes the importance of interactions and cumulative effects, but recognizes that current knowledge of the processes involved is insufficient to make specific recommendations for conceptual frameworks.

The conceptual approach suggested by Preston and Bedford (1988) addresses many critical issues, such as the need to define dimensions of scale and the importance of wetland size, shape, and location in the landscape. This approach and similar ones must be tested and evaluated so that a consensus may eventually emerge. A cumulative impact matrix is proposed that sets up additive, synergistic, and indirect categories, each capable of variation in space and time. Every interaction would be carefully examined to determine the likelihood of cumulative impact in any of the six categories. Because of its "magnifying glass" approach, such a matrix could be a very useful analytical tool, using existing methods to uncover all the information presently available about the behavior of the ecosystem of concern.

Russo, T.N. 1985. Perspectives on analyzing impacts related to multiple hydroelectric development. Pages 346-350 in F.W. Olson, R.G. White, and R.H. Hamre, eds Proceedings of the symposium on small hydropower and fisheries. American Fisheries Society, Western Division and Bioengineering Section.

Abstract. The Federal Energy Regulatory Commission Staff assessed the environmental impacts of 12 small-scale hydroelectric projects on 10 target resources in selected watersheds of the Upper San Joaquin River Basin, California in partial fulfillment of Section 306 of the Energy and Water Appropriation Act of 1983. The analytical approaches used in the Upper San Joaquin Study are generally consistent with the Cluster Impact Assessment Procedure proposed by staff to assess cumulative impacts. An examination of the study and how it was conducted can serve as a window on how staff views multiple hydroelectric development in river basins and the roles that resource agencies, developers, and native American and public interest groups may be expected to play in such studies in the future.

Salo, E.O., and C.J. Cederholm. 1981. Cumulative effects of forest management on watersheds--some aquatic considerations. Pages 67-78 in R.B. Standiford and S.I. Ramacher, eds. Cumulative effects of forest management on California watersheds. Univ. Cal. Agric. Sci. Spec. Publ. 3268. Berkeley.

Addition. The extinction of a salmonid stock due to the combined effects of logging and human harvest is discussed as one of four scenarios of impact in terms of the salmonid life cycle and population curves. Processes associated with land management that could operate in a cumulative manner upon aquatic populations are (1) increased sedimentation, (2) temperature changes, (3) changes in physical habitat, (4) changes in water quality, and (5) changes in water quantity and flow patterns. These may be measured individually, but predicting the cumulative effects of any two or more of these processes is not usually possible. The influence of sedimentation and organic debris on spawning success, species diversity, and production are briefly summarized. The authors maintain that despite gaps in knowledge of cumulative effects, enough basic information exists to improve land-management practices. Deficiencies exist in the numbers of educated managers and trained investigators, and in the understanding of the economics of forestry and fisheries on a regionwide basis.

Salwasser, H., and F.B. Samson. 1985. Cumulative effects analysis: an advance in wildlife planning and management. Trans. N. Amer. Wildl. Nat. Resour. Conf. 50:313-321.

Addition. This paper reviews the concepts of cumulative effects analysis and five technical and conceptual developments in wildlife planning that facilitate cumulative effects analysis. These developments are (1) specifying resource goals, (2) understanding the effects of habitat fragmentation on wildlife, (3) understanding the role of functional diversity on ecosystem productivity, (4) technologies for assessing temporal and spatial dynamics of ecosystems, and (5) empirical verification of assumptions about species-habitat relationships. These developments can help advance specific steps in the impact analysis process.

Sharp, J.M., and S.G. Appan. 1978. Cumulative effects of oil drilling and production on estuarine and near-shore ecosystems. Pages 57-73 in M.L. Wiley, ed. Estuarine interactions. Academic Press, New York.

Abstract. The paper describes a two-year, eight-season synoptic study to determine whether twenty-five years of intensive oil drilling and production had produced observable environmental or ecological change in Timbalier Bay and the adjacent offshore area in southern Louisiana. The primary approach involved comprehensive comparison of sites that were ecologically comparable and experienced natural variations in habitat conditions and inhabitant communities at essentially the same time and with essentially the same magnitude. Prior data, comparisons with other Gulf of Mexico ecosystem measurements, and accepted scientific causal relationships were also used to support interpretations. Biological, physical, chemical, and geological determinations made singly and in combination showed no evidence of significant ecological change and provided strong evidence of good ecological health.

Siegel, D.I. 1988. Evaluating cumulative effects of disturbance on the hydrologic function of bogs, fens, and mires. Environ. Manage. 12:621-626.

Abstract. Few quantitative studies have been done on the hydrology of fens, bogs, and mires. Consequently, predicting the cumulative impacts of disturbances on their hydrologic functions is extremely difficult. For example, few data are available on the role of bogs and fens with respect to flood desynchronization and shoreline anchoring. However, recent studies suggest that very small amounts of groundwater discharge are sufficient to radically modify mire surface-water chemistry and, consequently, vegetation communities and their associated surface-water hydrology. Bogs and fens are, in a sense, hydrobiologic systems, and any evaluation of cumulative impacts will have to (1) consider the complicated and little understood interactions among wetland hydrology, water chemistry, and biota, and (2) place the effect of individual wetland impacts within the context of the cumulative impacts contributed to the watershed from other geomorphic areas and land uses.

It is difficult to evaluate the potential cumulative impacts on wetland hydrology because geologic settings of wetlands are often complex and the methods used to measure wetland streamflow, groundwater flow, and evapotranspiration are inexact. This is especially so for bogs, fens, and mires underlain by thick organic soils. These wetlands, found in the circumboreal areas of North America, Europe, and Asia, are major physiographic features in eastern North America, northern Europe, and Siberia. Their very scale makes it difficult to quantify the hydrologic function accurately. The hydrology of small bogs and fens found elsewhere is just as poorly understood because of conflicting conceptual models of pertinent hydrologic processes. This article (1) reviews our current understanding of the hydrologic function of bogs, fens, and mires at different scales and in different physiographic settings and (2) presents hypotheses on potential cumulative impacts on the hydrologic function that might occur with multiple disturbances.

Sonntag, N.C., R.R. Everitt, L.P. Rattie, D.L. Colnett, C.P. Wolf, J.C. Truett, A.H.J. Dorcey, and C.S. Holling. 1987. Cumulative effects assessment: a context for further research and development. A report to the Canadian Environmental Assessment Research Council. Minister of Supply and Services Canada. Cat. No. En 106-7/1987E.

Abstract (from the Executive Summary). The purpose of this study is to review current practices for identifying and assessing cumulative effects in order to formulate recommendations that the Canadian Environmental Assessment Research Council (CEARC) may use in drafting a research prospectus. This report represents a preliminary analytical framework for cumulative effects assessment (CEA), which provides some common ground in the analysis of the case studies, and brings together, in one model, the spatial, temporal, and system dimensions of cumulative effects. Three case studies documenting some Canadian experience with assessing and managing cumulative effects are presented in the context of the framework. Finally, knowledge of various researchers and practitioners in environmental impact assessment and CEA are incorporated in the recommendations.

Stakhiv, E.Z. 1986. Cumulative impact analysis for regulating decisionmaking. Pages 213-222 in J.A. Kusler and P. Riexinger, eds. Proceedings of the national wetland assessment symposium. ASWM Tech. Rep. 1. Association of State Wetland Managers, Chester, VT.

Addition. The author provides background to the issues involved within the U.S. Army Corps regulatory program and the problems presented by a "prescriptive, reductionist view of impact analysis." The author argues that if cumulative impact analysis is to have any impact in decisionmaking, a shift in evaluation philosophy "away from highly reductionist tracing of individual impacts to one of assessing consequences of actions and policies measured against a set of desired goals and objectives" is necessary. Under this approach an evaluation framework is provided in detail. Finally, the application of a common mathematical linear programming technique is demonstrated with a relatively simple evaluation model. The model abstracts some of the key aspects of the Corps' regulatory decisionmaking by devising a hypothetical scenario reflecting the gradual development of an estuarine-wetlands system. The author concludes with a discussion of the insights and benefits offered by this approach to impact analysis.

Stakhiv, E.Z. 1988. An evaluation paradigm for cumulative impact analysis. Environ. Manage. 12:725-748.

Abstract. Cumulative impact analysis is examined from a conceptual decision-making perspective, focusing on its implicit and explicit purposes as suggested within the policy and procedure for environmental impact analysis of the National Environmental Policy Act of 1969 (NEPA) and its implementing regulations. In this article it is also linked to different evaluation and decision-making conventions, contrasting a regulatory context with a comprehensive planning framework. The specific problems that make the application of cumulative impact analysis a virtually intractable evaluation requirement are discussed in connection with the Federal regulation of wetlands uses. The relatively familiar U.S. Army Corps of Engineers' (the Corps) permit program, in conjunction with the Environmental Protection Agency's (EPA) responsibilities in managing its share of the Section 404 regulatory program requirements, is used throughout as the realistic context for highlighting certain pragmatic evaluation aspects of cumulative impact assessment.

To understand the purposes of cumulative impact analysis (CIA), a key distinction must be made between the implied comprehensive and multiobjective evaluation purposes of CIA, promoted through the principles and policies contained in NEPA, and the more commonly conducted and limited assessment of cumulative effects, which focuses largely on the ecological effects of human actions. Based on current evaluation practices within the Corps' and EPA's permit programs, it is shown that the commonly used screening approach to regulating wetlands uses is not compatible with the purposes of CIA, nor is the environmental impact statement an appropriate vehicle for evaluating the variety of objectives and trade-offs needed as part of CIA. A heuristic model that incorporates the basic elements of CIA is developed, including the idea of trade-offs among social, economic, and environmental protection goals carried out within the context of environmental carrying capacity.

Stakhiv, E.Z., and E.C. Vlachos. 1979. Analysis of cumulative impacts for Corps permit activities. Institute for Water Resources, United States Army Corps of Engineers, Fort Belvoir, VA. Contract Report 79-4. 72 pp.

Abstract (from the Foreword). The purpose of the report is the timely dissemination of concepts for analysis of cumulative impacts (ACI), both to the field operating agencies of the Corps of Engineers and to the Federal agencies that interact with the Corps' Regulatory Program. This report represents the culmination of the second stage of a three-phase approach to the study of techniques for the "Analysis of Cumulative Impacts (ACI) for Corps Permit Activities." The study is being conducted by the U.S. Army Engineer Institute for Water Resources (IWR) for the Chief of the Regulatory Functions Branch at the Office of the Chief of Engineers. The first stage encompassed a state-of-the-art review that arrayed the concepts inherent in ACI against current methods utilized for impact analysis to complement the more specific requirements of the Corps' regulatory program. The second phase of the ACI study consisted of a Workshop on Analysis of Cumulative Impacts, which brought together a tripartite assemblage of interests representing academia, Corps field practitioners, and Corps policy implementors.

Part I of this report represents the individual reflections on ACI of Stakhiv (Section A) and of Vlachos (Section B), both of whom delve into the underlying principles of ACI. Vlachos concentrates on the theoretical and philosophical bases for ACI, recommending a departure from traditional, direct cause-effect impact analysis to a broader, macro-level or holistic analysis of environmental consequences. Stakhiv reviews the basis for ACI as derived from the implied and intended needs of the Corps Regulatory Program and outlines a program for further inquiry that is focused on the perceived practical needs of the field, integrated with the significant findings of the workshop. This shall serve as the basis for the third stage of ACI.

A list of strategies for pursuing ACI is proposed for more detailed explication and development of concepts to complement this initial study of ACI. A number of analytical and data management techniques are proposed for near-term applications to the needs of rapid preparation of preliminary environmental assessments for issuance of the public notice.

Standiford, R.B., and S.I. Ramacher, eds. 1981. Cumulative effects of forest management on California watersheds: an assessment of status and need for information. Univ. Cal. Agri. Sci. Spec. Publ. 3268. Berkeley. 109 pp.

Addition. The objectives of the conference were to identify what cumulative effects are, determine the present state of knowledge, determine what mechanics of measurement are available, and identify information needs. Nine chapters deal with impacts on watershed processes and soil productivity, on wildlife, on aquatic life, and on vegetation dynamics, and discuss the economics of cumulative effects. Although each resource has a sizeable amount of research to guide its management, there is little information on how to relate these data to resource interaction. In response to the clear gap of knowledge on cumulative effects, especially about the amount of sedimentation that can be expected from different degrees of disturbance and the effect of sediment on water quality and fisheries, a proposed list of 12 studies was formed.

[See also: Camp; Fairfax; Rice; Salo and Cederholm; Taber et al.; Zinke; Zivnuska.]

Steele, T.D. 1982. Cumulative hydrologic impacts of energy development. Pages 400-407 in F. Kilpatrick and D. Matchett, eds. Proceedings of the western conference on water and energy: technical and policy issues. American Society of Civil Engineers, New York, NY.

Abstract. Cumulative-impact analyses of energy development tend to guide a number of interrelated hydrologic studies which are more localized in space, over time, or in technical scope. Initial emphasis of such analyses concentrates on physical changes in the hydrologic system caused by mining, transport, conversion, and other utilization of the several types of energy resources. These would include changes in ground water and surface water systems, such as impacts on infiltration rates, runoff characteristics, water quality, water supply, vegetation cover, and wildlife habitat. However, the indirect effects of population shifts or growth and of associated economic development in the impacted region are an integral part of a cumulative-impact analysis. Certain water quality and quantity effects may be dominated by these indirect factors rather than the direct effects of mining and/or conversion of energy resources.

Guidelines and proposed techniques for conducting cumulative-impact assessments of regions affected by energy development are discussed. These include specifications of the types and detail of field data and other relevant information, an integration of data analysis and modeling procedures, and descriptions of presenting the resultant information. Finally, identified information gaps critical to a cumulative hydrologic impact assessment are recommended and prioritized as topics for future studies.

Stone, J.H., and G.F. McHugh. 1977. Simulated hydrologic effects of canals in Barataria Basin: a preliminary study of cumulative impacts. Final report for the Louisiana State Planning Office by Center for Wetland Resources, Louisiana State University, Baton Rouge. 40 pp.

Abstract. Computer simulations of the hydrography of Barataria Basin indicate significant hydrologic changes due to navigation and transportation canals. The simulations compared hydrologic parameters in the Basin before and after the construction of the Barataria and Intracoastal waterways and the canals associated with eight oil and gas fields. The waterways accounted for about 90 percent of the simulated changes; the remaining 10 percent was due to the canals of the eight oil and gas fields. The effects of oil and gas canals are individually small, but they are cumulative and, overall, probably are just as significant as those due to waterways, since there are approximately 90 fields in the Basin.

The following hydrologic parameters were measured: area flooded versus nonflooded, water heights over a tidal cycle, and total water flow at several locations over a tidal cycle. Canals increased the area of wetland, especially in the northern half of the Basin; for example, flooded areas increased between 11 and 13 percent. Water heights increased on the average by about 2 inches, or more than 9 percent above normal conditions; this effect was evident only north of Little Lake. Total water flow over a 25-hour tidal cycle increased between 7 and 16 percent in the intermediate marshes. Water flow at individual exchange points in the freshwater marshes was reduced between 20 and 70 percent of normal. Water flow through tidal passes was not changed.

Systematic studies of these effects, how to mitigate them, and how they are related to biological production are badly needed. Large-scale development projects, which require waterways or canals, should be carefully evaluated and monitored to determine their full environmental effects. Although the hydrologic effects of individual canals of oil and gas fields are probably small (especially when evaluated at the basin level), their effects are cumulative, and so we recommend that additional canals be added only if absolutely necessary; and, when they're no longer useful, they should be refilled and refurbished. A series of workshops to be held with public agencies and private interests to discuss these results and their management implications was also recommended.

Stout, D.J. 1985. A practical approach to cumulative impact assessment. Pages 373-376 in F.W. Olson, R.G. White, and R.H. Hamre, eds. Proceedings of the symposium on small hydropower and fisheries. American Fisheries Society, Western Division and Bioengineering Section.

Abstract. More than 600 sites have been proposed for hydropower projects in Washington State's Snohomish River Basin within the last several years. In an attempt to provide for reasonable hydropower development that is compatible with fishery and wildlife management goals, the responsible Federal and State agencies and Indian tribes developed a procedure for project impact assessment. This procedure has been presented in the *Snohomish Guidelines for the Evaluation of Hydropower Projects* that: (1) outlines parameters to be evaluated for each project, (2) recommends techniques to be used in assessing each parameter, and (3) describes an approach for the sequential analysis of project-specific and cumulative impacts.

At this time, the *Snohomish Guidelines* have been used to analyze two projects. The *Guidelines* have provided a clear framework within which to evaluate these hydropower proposals. Agency and tribal biologists are required to establish management goals, make precise recommendations regarding assessment techniques, and set "thresholds of significance" for the evaluation of study results. Project proponents are required to do detailed studies on selected parameters and present the data in terms of a "project impact zone" to allow analysis of potential cumulative impacts. The result is a clear path by which the acceptability of projects can be evaluated for impacts both project-specific and cumulative.

Stout, D.J. 1988. Preventing cumulative impacts: the Washington experience. Pages 204-206 in J.A. Kusler, M.L. Quammen, and G. Brooks, eds. Proceedings of the national wetland symposium: mitigation of impacts and losses. ASWM Tech. Rep. 3. Association of State Wetland Managers, Chester, VT.

Abstract (from the Introduction and Summary). In the past few years cumulative impact analysis has become a major issue in Washington State. This is due to the huge number of proposals for hydroelectric projects, and to the concern for protection of estuarine habitats, which are important for salmon and steelhead. The responsible resource agencies and tribes (agencies) have realized that traditional methods for evaluating the site-specific and cumulative impacts from a flood of project proposals are not adequate. This paper describes the approach that has been developed in Washington State for evaluating and preventing negative cumulative impacts.

The approach to preventing cumulative impacts that has been developed in the State of Washington has resulted from a strong consensus among the various agencies regarding management goals for important fish and wildlife resources. The goal of this procedure is to avoid cumulative impacts through appropriate siting, design, operation, and timing of projects. It reflects the need for high quality data upon which to base decisions on project proposals. This approach has been widely accepted by developers and decision-makers because the agencies have attempted to provide clear and consistent guidance and goals.

Stull, E.A., M.B. Bain, J.S. Irving, K.E. LaGory, and B.W. Witmer. 1987. Methodologies for assessing the cumulative environmental effects of hydroelectric development on fish and wildlife in the Columbia River Basin. Vol. 1: Recommendations. Prepared for Bonneville Power Administration. Argonne National Laboratory, Contract No. DEAI79-48BP19461. 142 pp.

Abstract. This volume is the first of a two-part set addressing methods for assessing the cumulative effects of hydropower development on fish and wildlife in the Columbia River Basin. Species and habitats potentially affected by cumulative impacts are identified for the basin, and the most significant effects of hydropower development are presented. Then, current methods for measuring and assessing single-project effects are reviewed, followed by a review of methodologies with potential for use in assessing the cumulative effects associated with multiple projects. Finally, two new approaches for cumulative effects assessment are discussed in detail. Overall, this report identifies and reviews the concepts, factors, and methods necessary for understanding and conducting a cumulative effects assessment in the Columbia River Basin.

Stull, E.A., K.E. LaGory, and W.S. Vinikour. 1987. Methodologies for assessing the cumulative environmental effects of hydroelectric development on fish and wildlife in the Columbia River Basin. Volume 2: Example and procedural guidelines. Prepared for Bonneville Power Administration. Argonne National Laboratory, Contract No. DEAI79-48BP19461. 92 pp.

Abstract. This volume is the second of two volumes that address methods for assessing the cumulative effects of hydropower development on fish and wildlife in the Columbia River Basin. A hypothetical example of multiple hydroelectric development is used to demonstrate the applicability of the integrated tabular methodology (ITM) that was recommended for cumulative effects assessment in Volume 1. The example consists of an existing mainstem dam and four proposed small hydroelectric developments in a small river basin containing elk summer and winter range and chinook salmon spawning areas. Single-project impact assessments are used collectively in the methodology to estimate the cumulative effects of the projects on elk and salmon. The steps in cumulative assessment are (1) establishing a conceptual and schematic representation of each cumulative effect, (2) calculating interaction coefficients for each pair of projects, (3) developing interaction and impact matrices, (4) multiplying these matrices, (5) evaluating the contribution of shared project features to cumulative effects, and (6) incorporating the effects of already existing projects. The ITM is most effective when single-project assessments are accomplished in a detailed, quantitative manner. The methodology involves the use of impact response curves (such as fry emergence as a function of fine sediment or habitat suitability as a function of road density) for each impact being assessed. However, it is possible to accomplish cumulative assessment without the use of response curves if less detailed or only qualitative information is available.

Stull, E.A., M.B. Bain, J.S. Irving, K.E. LaGory, R.D. Olsen, and G.W. Witmer. 1988. Cumulative impact assessment: issues to consider in selecting a cumulative assessment method. Waterpower '87, vol. 1, 636-641.

Abstract. Because widespread interest in the subject is new, there are no standard or generally recognized methods for cumulative impact assessment. A method should include procedures for (1) evaluating the combined effects of more than one action, (2) evaluating nonadditive, as well as additive, relationships between projects, (3) assessing the combined indirect effect of projects on fish and wildlife populations, in addition to direct effects on the physical environment and fish and wildlife habitats, and (4) assessing any of the 16 types of impacts to 40 species of fish and wildlife. The need to prepare a cumulative impact assessment presents many challenges to engineering and environmental professionals. The purpose of this paper is to present some guidance that will assist in clarifying some of those challenges.

Taber, R.D., S.D. West, and K.J. Raedeke. 1981. Some cumulative effects of forest management on wildlife. Pages 51-66 in R.B. Standiford and S.I. Ramacher, eds. Cumulative effects of forest management on California watersheds. Univ. Cal. Agri. Sci. Spec. Publ. 3268. Berkeley.

Addition. Consequences of production forest management for wildlife are discussed in terms of the loss of habitat heterogeneity. Practices such as slash, snag, and scarification site preparation, logging systems, size and spacing of cuts, residues, stand protection, fertilization, stand thinning, species choice, rotation length, road building, and landscape pattern may or may not have deleterious effects depending on their management and implementation. The authors maintain that there is great unrealized potential for avoiding deleterious effects of forest management.

U.S. Federal Energy Regulatory Commission. 1986a. Draft environmental impact statement for 15 hydroelectric projects in the Salmon River Basin, Idaho. Docket No. EL-85-19-103. FERC/DEIS-0044. v.p.

Abstract. Fifteen hydroelectric projects that would produce an annual total of 93.5 gwh of electric power and would be sited in the Salmon River Basin, Idaho, have been evaluated for their environmental effects, including cumulative effects, and economic feasibility. Twenty-one hydroelectric sites; a coal-fired, steam electric plant; conservation; and no action were evaluated as alternatives to the proposed actions. The 15 proposed projects were evaluated with and without staff-recommended mitigation and then placed into three development scenarios: (1) negligible cumulative impacts, not allowing the development of any projects, (2) low, insignificant cumulative impacts, allowing the development of five projects, and (3) moderate to high cumulative impacts, allowing the development of all 15 proposed projects. The staff recommended the second development scenario because the projects had insignificant environmental impacts and were economically feasible. This would produce 13.7 gwh of electric power annually.

Addition. Cumulative impacts to chinook salmon, steelhead trout, resident trout, elk, mule deer, gray wolf, and riparian resources were evaluated using the matrix method. Impacts to the economic value of the fisheries were also evaluated, as well as analyses of impacts with staff-recommended mitigation measures.

U.S. Federal Energy Regulatory Commission. 1986b. Final environmental impact statement for seven hydroelectric projects in the Owens River Basin, California. Docket No. EL85-19-102. FERC/DEIS-0041. v.p.

Abstract. Seven hydroelectric projects that would produce a total of 63 gwh per year of electric power and would be sited in the Owens Valley, California, have been evaluated for their environmental effects and economic feasibility. Four hydroelectric projects that would produce 13.1 gwh and a geothermal plant designed to produce 81 gwh were evaluated as alternatives. These 12 projects were evaluated individually and then placed into four development scenarios: (1) seven projects as proposed, (2) seven projects as mitigated by the staff, (3) three projects as mitigated by the staff, two alternative projects, and the geothermal project, and (4) no action. The staff recommended the third development scenario because the projects had acceptable environmental impacts and were economically feasible. This alternative would produce 97.2 gwh per year of electric power.

Addition. The cumulative impacts of these projects on resident trout, riparian vegetation, riparian-associated wildlife, aesthetics, recreation, and the local economy were evaluated without and with staff-recommended mitigation measures. Impact matrices were used to help determine the degree of disturbance that would be caused by these projects. The most serious aquatic impacts were identified as dewatering, entrainment or impingement, and sedimentation.

U.S. Federal Energy Regulatory Commission. 1986c. Snohomish River Basin cluster impact assessment procedure, Washington. Draft Environmental Impact Statement. Docket No. EL-85-19-101. FERC/DEIS-0042. v.p.

Abstract. Seven hydroelectric projects that would produce a total of 207.6 gwh per year of electric power and would be sited in the Snohomish River Basin, Washington, have been evaluated for their environmental effects, including cumulative effects, and economic feasibility. Fourteen hydroelectric projects, a geothermal plant, conservation, and no action were evaluated as alternatives. The seven proposed projects were evaluated with and without staff-recommended mitigation and then placed into three development scenarios: (1) negligible cumulative impacts, allowing the development of two projects, (2) low, nonsignificant cumulative impacts, allowing the development of four projects, and (3) moderate-to-high cumulative impacts, allowing the development of all seven proposed projects. The staff recommended the second development scenario because the projects had nonsignificant environmental impacts and were economically feasible. This alternative would produce 107.8 gwh per year of electric power.

Addition. The target resources evaluated for this basin were salmon, steelhead trout, sea-run trout, resident trout, black-tailed deer, and bald eagles. A matrix method to determine the additive, site-specific impacts and the interactive impacts of various combinations of the seven proposed projects was used.

U.S. Forest Service Region 5. 1988. Cumulative off-site watershed effects analysis. Chapter 20 in Region 5 Forest Service Handbook 2509.22: Soil and water conservation handbook. Amendment No. 1 (July 1988). San Francisco, California. v.p.

Abstract (from the Introduction). This chapter describes the cumulative off-site watershed effects (CWE) assessment procedure used on National Forest system lands within the State of California. Known information used in the analysis produces an objective, reproducible, and professional assessment of the combined effects of all past, present and reasonably foreseeable future management actions on downstream beneficial uses of water. Application of the procedure is guided by a conceptual CWE model. Both the model and procedure are refined and modified as results of monitoring and technical studies become available.

This chapter limits the scope of the methodology to only evaluating the susceptibility of CWE on downstream beneficial uses of water. The procedure is useful for evaluating both beneficial and adverse CWE. Beneficial effects may result from management actions such as watershed improvement projects and special project mitigation. Adverse effects may result from multiple land use activities which combine to cause detrimental changes in watershed hydrology or sedimentation from landsliding and soil erosion. The procedure described in this chapter is similar to decision making models which use relative rankings and weightings.

U.S. General Accounting Office. 1988. Energy regulation: opportunities for strengthening hydropower cumulative impact assessments. Report to the Chairman, Committee on Energy and Commerce, House of Representatives, GAO-RCED-88-82. 20 pp.

Abstract (from the Letter of Introduction). In summary, we found that before authorizing the use of CIAP (Cluster Impact Assessment Procedure) in 1985, FERC (Federal Energy Regulatory Commission) formally announced its plans for using the procedure and requested public comment on their appropriateness. FERC has since used the River Basin EIS (environmental impact statement) procedure in lieu of CIAP and apparently plans to use it to carry out future assessments. However, FERC has yet to publicly announce its plans for using the River Basin EIS and to request public comment on them, as it did before adopting CIAP. We also found that the preparation of comprehensive river basin plans can help resolve disagreements between FERC and other Federal and State agencies about the way in which FERC carries out cumulative impact assessments. We are recommending that FERC publicly announce its plans for conducting future assessments and request public comment on their appropriateness. We are also recommending that FERC take an active role in encouraging and facilitating the development of comprehensive river basin plans by States and Federal agencies.

Vlachos, E. 1982. Cumulative impact analysis. Impact Assessment Bulletin 1:60-70.

Addition. This paper offers a definition of cumulative impacts in the context of existing legal mandates, discusses the theory and practice of cumulative impacts, and suggests some pragmatic strategies of cumulative impact assessment and evaluation. Direct and indirect effects are considered within the discussion of combined effects that may be small and individually insignificant but that lead to collectively significant actions. An extended time horizon and interactions are two concepts basic to the legal definition of cumulative impacts. Conceptual clarity is constantly being searched for, and the author poses questions to help find it. The author also discusses three interrelated conceptual dimensions: aggregative, interactive, and diachronic. Critical elements in a realistic assessment strategy are the nature of the action, the scale of the transformation, the rate of change, and the arena of operation. Relevant methodological tactics within the assessment strategy fall into three categories: retrospective, prospective, and policy analysis. The author reviews these concepts, the prevailing methodological practices that he has observed in the literature, and ongoing efforts to assess cumulative impacts.

Vlachos, E. 1985. Assessing long-range cumulative impacts. Pages 49-80 in V.T. Covello, J.C. Manipower, J.M. Stallen, and V.R.R. Uppuluri, eds. Environmental impact assessment, technology assessment, and risk analysis. NATO ASI Series Vol. G4. Springer-Verlag, Berlin.

Abstract. Cumulative impacts can be defined as the totality of interactive impacts over time, i.e., the sum incremental, synergistic effects caused by all current and reasonably foreseeable actions over time and space. The concept of cumulative impacts recognizes that although individual actions may have insignificant effects, in their aggregate (especially through interaction), they can become quite significant. An attempt is made throughout the paper to delineate characteristics and types of cumulative impacts. Three major dimensions are particularly emphasized: "aggregative" cumulative impacts, which indicate addition or summing up of impacts of identical or related actions; "interactive" cumulative impacts, which underscore the cross-effects of related actions; and "diachronic" cumulative impacts, which underline the influence and importance of an extended time horizon.

Since a cumulative impact assessment represents a higher order of analysis and evaluation of cause-effect linkages, new conceptual and methodological approaches become necessary. Two major approaches, "sensitivity" (mapping) and "additive" (threshold), are explicated, and a series of techniques in retrospective assessment, prospective assessment, and policy analysis are reviewed as relevant for an integrated cumulative impact assessment. The conclusions emphasize the observation that a derived "cumulative" approach involves a different way of thinking, encompassing a combination of broader geographical scope, many inducers or actions, and extended time horizon. The search for cumulative impacts is central to integrated, futures-oriented planning and to the quest for accounting for a wide gamut of indirect, secondary, aggregative effects of a multitude of actions characterizing a complex, interdependent society.

Waldichuk, M. 1986. Management of the estuarine ecosystem against cumulative effects of pollution and development. Pages 93-105 in Canadian Environmental Assessment Research Council and United States National Research Council. Cumulative environmental effects: a binational perspective. Minister of Supply and Services Canada.

Addition. "The purpose of this paper is to examine the cumulative effects of pollution and development in estuaries." The Fraser River estuary and the Squamish River estuary, with an emphasis on their salmon fisheries, are presented as case histories, following a description of general considerations of estuarine ecosystems and legislative controls. Generally, studies of environmental impact conducted in British Columbia have ignored the cumulative effect of other pollution inputs or shoreline developments in estuaries. Recommendations provided by the authors include the development of a conceptual framework within which an evaluation of cumulative impacts can be made, balance sheets of positive and negative effects, and laboratory research.

Walker, D.A., E.F. Binnian, N.D. Lederer, E.A. Nordstrand, R.H. Meehan, M.D. Walker, and P.J. Webber. 1986. Cumulative landscape impacts in the Prudhoe Bay Oil Field 1949-1983. Institute of Arctic and Alpine Research, University of Colorado, Boulder. Interagency agreement DE-AI06-84RL10584. 51 pp.

Abstract (from the Summary and Conclusions). The mapping program for the Prudhoe Bay field has made several important contributions toward the problem of cumulative impacts in northern Alaska. It has resulted in an approach that is useful for long-term monitoring of oil field growth and impacts that can be related to the natural geobotanical character of the landscape. Although a few types of small impacts were not mapped for this project (e.g., narrow linear features such as pipelines, power lines, off-road vehicle trails, and fences), the scale of the IGHDM (Integrated Geobotanical and Historical Disturbance Map) method (1:6000) is a practical one that utilizes the topographic maps that are produced by the oil industry for its field operations. The method could also prove useful in the planning process for new developments. The automated mapping methods lend themselves well to creative planning, whereby roads, pads, and even anticipated indirect impacts can be overlain against the background of the natural terrain. The procedures are appropriate for analysis of high-impact projects that cover relatively small areas. For very large projects, such as long utility corridors or a comprehensive plan for the entire North Slope, the IGHDM methods could be integrated into planning procedures at smaller scales. Planning at this scale would require different data bases, such as Landsat-derived classifications and small-scale GIS data bases.

The analysis we have conducted here could be utilized in an extrapolative analysis to predict cumulative landscape impacts for future oil fields. Such an approach would likely find that within 50 years most of the North Slope coastal plain would be affected by road networks and pipeline systems. Holistic planning on the North Slope must involve much more than extrapolation from the present to some time when the entire ecosystem breaks down. It should also include a practical compromise that permits resource development for a well-developed economy while preserving as much of the natural environment of northern Alaska as possible.

Walker, D.A., P.J. Webber, E.F. Binnian, K.R. Everitt, N.D. Lederer, E.A. Nordstrand, and M.D. Walker. 1987. Cumulative impacts of oil fields on northern Alaskan landscapes. Science 238:757-761.

Abstract. Proposed further developments on Alaska's Arctic Coastal Plain raise questions about cumulative effects on Arctic tundra ecosystems of development of multiple large oil fields. Maps of historical changes to the Prudhoe Bay Oil Field show indirect impacts can lag behind planned developments by many years, and the total area eventually disturbed can greatly exceed the planned area of construction. For example, in the wettest parts of the oil field (flat thaw-lake plains), flooding and thermokarst covered more than twice the area directly affected by roads and other construction activities. Protecting critical wildlife habitat is the central issue for cumulative impact analysis in northern Alaska. Comprehensive landscape planning with the use of geographic information system technology and detailed geobotanical maps can help identify and protect areas of high wildlife use.

Walker, D.A., P.J. Webber, M.D. Walker, N.D. Lederer, R.H. Meehan, and E.A. Nordstrand. 1986. Use of geobotanical maps and automated mapping techniques to examine cumulative impacts in the Prudhoe Bay oilfield, Alaska. Environ. Conserv. 13(2):149-160.

Abstract. This report demonstrates some of the flexibility of the automated geobotanical map data base. The data base has obvious potential for day-to-day planning and record-keeping within the tundra oilfield. It also has many scientific applications. Bird habitat, ground-ice, plant distribution patterns, and many other features can all be related to the basic data set. The data set can also be readily expanded to include other factors, such as geology and habitat attributes. It must be emphasized, however, that derived maps and models produced from the data base are only as good as the understanding of the processes involved. They will remain "blunt tools" for land-use planning until there are thorough studies of tundra response to disturbance that are specifically related to the various geobotanical units.

Maps can only depict relatively major physical changes to the terrain. They cannot depict total cumulative impact, which includes other factors such as the actual effects on wildlife populations (although the effects on wildlife habitat can be displayed on a map). They do, however, depict the accumulated sum of development and the associated visual impacts. In spite of the clear need to examine cumulative impact in the face of massive development occurring on the North Slope, there exists very little theory or methodology regarding cumulative impact. The method presented here for depicting complex "historical" change is a necessary first step towards a comprehensive methodology for evaluating cumulative impact. Although there is uncertainty as to whether site-specific "histories" and dynamics can be extrapolated to other areas, "historical" studies can point out the flaws of past practices and help in the development of more effective regulatory methods.

Weaver, J., R. Escano, D. Mattson, T. Puchlers, and D. Despain. 1986. A cumulative effects model for grizzly bear management in the Yellowstone ecosystem. Pages 234-245 _in_ G.P. Contreras and K.E. Evans, eds. Proceedings - grizzly bear habitat symposium. U.S. Forest Service Intermountain Research Station General Technical Report INT-207.

Abstract. Cumulative effects may be defined as the combined effect upon a species and its habitat resulting from multiple land uses over space and time. A Cumulative Effects Model (CEM) has been designed to (1) quantify individual and collective effects of land uses and activities in space and through time and (2) provide managers an analytic tool for evaluating alternative decisions relative to grizzly bear recovery goals and objectives. The CEM is composed of three submodels: habitat, displacement, and mortality. The habitat and displacement submodels determine the habitat effectiveness value of an area, while the mortality submodel portrays mortality risks. The submodels integrate basic variables that are significant and subject to management.

The habitat submodel incorporates four variables: (1) food and thermal cover, (2) habitat diversity, (3) seasonal equity, and (4) denning suitability. These variables combined indicate the year-round habitat quality of an area. The displacement submodel includes four variables of human activity: (1) location relative to hiding cover, (2) type (motorized or nonmotorized), (3) nature (linear, point, or dispersed), and (4) intensity (high or low use, day or overnight use). Displacement is characterized by a coefficient of disturbance and by an associated zone of influence. The mortality submodel incorporates four variables of human activity: (1) location relative to habitat quality, (2) nature, (3) intensity and sanitation, and (4) firearms. By integrating the submodels, the CEM provides two basic outputs: habitat effectiveness value and mortality risk index. Once thresholds appropriate for grizzly bear recovery are established for habitat effectiveness and mortality risk, managers can manipulate the numerous variables and analyze the competitive and cumulative effects of various land uses through computer simulations.

Weaver, J.L., R.E.F. Escano, and D.S. Winn. 1987. A framework for assessing cumulative effects on grizzly bears. Trans. N. Amer. Wildl. Nat. Resour. Conf. 52:364-376.

Abstract (from the Design). The Cumulative Effects Assessment (CEA) model is designed to (1) quantify individual and collective effects of land uses and activities in space and time, and (2) provide managers with an analytic tool for evaluating alternative decisions relative to grizzly bear conservation goals and objectives. The CEA model is composed of three submodels--habitat, displacement, and mortality. The habitat and displacement submodels determine the effective habitat value of an area, while the mortality submodel determines the mortality risks. The submodels integrate basic variables that appear significant to bears and are subject to management.

The habitat submodel incorporates three variables: (1) food and cover, (2) habitat diversity, and (3) seasonal equity. Denning suitability is considered separately. These basic variables combined indicate the year-long suitability of an area. The displacement submodel includes four variables of human activity: (1) location relative to hiding cover, (2) nature of activity (motorized, nonmotorized or explosive), (3) type of activity (linear, point or dispersed), and (4) disturbance intensity (high or low use, diurnal or 24-hour). Displacement is characterized by a coefficient of disturbance and by an associated zone-of-influence. The displacement submodel is directly linked to the habitat submodel through the cover variable. The mortality submodel incorporates four basic variables regarding human activity: (1) habitat quality, (2) type of activity, (3) intensity, and (4) sanitation. The relative risk of mortality can be compared among activities. The mortality submodel is linked to the habitat submodel through habitat quality and to the displacement submodel through the variables of human activity. By integrating the submodels, the CEA model provides two basic outputs: habitat effectiveness value (net "habitat units") and mortality risk index.

Weller, M.W. 1988. Issues and approaches in assessing impacts on waterbird habitat in wetlands. Environ. Manage. 12:695-701.

Abstract. Wetlands are attractive to vertebrates because of their abundant nutrient resources and habitat diversity. Because they are conspicuous, vertebrates commonly are used as indicators of changes in wetlands produced by environmental impacts. Such impacts take place at the landscape level, where extensive areas are lost; at the wetland complex level, where some (usually small) units of a closely spaced group of wetlands are drained or modified; or at the level of the individual wetland, through modification or fragmentation that impacts its habitat value. Vertebrates utilize habitats differently according to age, sex, geographic location, and season, and habitat evaluations based on isolated observations can be biased. Current wetland evaluation systems incorporate wildlife habitat as a major feature, and the habitat evaluation procedure focuses only on habitat. Several approaches for estimating bird habitat losses are derived from population curves based on natural and experimentally induced population fluctuations. Additional research needs and experimental approaches are identified for addressing cumulative impacts on wildlife habitat values.

Whigham, D.F., C. Chitterling, and B. Palmer. 1988. Impacts of freshwater wetlands on water quality: a landscape perspective. Environ. Manage. 12:663-671.

Abstract. In this article, we suggest that a landscape approach might be useful in evaluating the effects of cumulative impacts on freshwater wetlands. The reason for using this approach is that most watersheds contain more than one wetland, and effects on water quality depend on the types of wetlands and their position in the landscape. Riparian areas that border uplands appear to be important sites for nitrogen processing and retention of large sediment particles. Fine particles associated with high concentrations of phosphorus are retained in downstream wetlands, where flow rates are slowed and where the surface water passes through plant litter. Riverine systems also may play an important role in processing nutrients, primarily during flooding events. Lacustrine wetlands appear to have the least impact on water quality, due to the small ratio of vegetated surface to open water. Examples are given of changes that occurred when the hydrology of a Maryland floodplain was altered.

Williamson, S.C., C.L. Armour, and R.L. Johnson. 1986. Preparing a FWS cumulative impacts program: January 1985 workshop proceedings. U.S. Fish Wildl. Serv. Biol. Rep. 85(11.2). 37 pp.

Abstract. This report presents the results of a second U.S. Fish and Wildlife Service workshop on cumulative impacts. Workshop participants identified a multitude of problems that are having a cumulatively significant impact on the fish and wildlife resources of the Nation and categorized these into five types: water development, land-use change, erosion and eutrophication, chemical disposal, and overharvest. Seventy-eight constraints that are currently preventing cumulative impact assessment were identified and assigned to four categories: define terms, marketing, assessment tools, and institutional mechanisms. Potential solutions that would remove the constraints were identified and prioritized for each of the categories. Fourteen action items for advancing the cumulative impact program were assigned to specific Service entities for implementation.

Williamson, S.C., C.L. Armour, G.W. Kinser, S.L. Funderburk, and T.N. Hall. 1987. Cumulative impacts assessment: an application to Chesapeake Bay. Trans. N. Amer. Wildl. Nat. Resour. Conf. 52:377-388.

Abstract (from the Introduction and Conclusion). This paper describes a cumulative impacts assessment process and the results to date from its prototype application to Chesapeake Bay. Cumulative impacts, as used here, are the accumulation of all effects of human actions and natural events on the ecological environment. Odum called this situation "the tyranny of small decisions" because no decision was ever consciously made to allow cumulative impacts. Causes of eventual cumulative impacts problems are usually separated in space or time and frequently differ in degree; therefore, the reduction in environmental quality is gradual and often goes unnoticed.

In this cumulative impacts assessment process, we used a few simple techniques to study a complex situation. We generated a hypothesis that restoration of submerged aquatic vegetation should be a major thrust of the Chesapeake Bay restoration. Submerged aquatic vegetation decline is a keystone problem that can be measured, monitored, and managed, and it directly relates to declines in abundance of migratory fish and wildlife species. We believe that submerged aquatic vegetation should be a central focus of the restoration of Chesapeake Bay. Distribution and biomass of submerged aquatic vegetation, as opposed to measurements of nutrient concentrations and toxic chemical loadings, can serve as an integrator of human impacts on the bay and as a quantitative indicator of the environmental quality of the bay. Living resources instead of water quality parameters would serve as excellent long-term measures of the success of our restoration efforts.

Winn, D.S., and K.R. Barber. 1985. Cartographic modeling: a method of cumulative effects appraisal in the Greater Yellowstone ecosystem. Pages 35-41 in R.D. Comer, T.G. Baumann, P. Davis, J.W. Monarch, J. Todd, S. VanGytenbeek, D. Wills, and J. Woodling, eds. Issues and technology in the management of impacted western wildlife. Proceedings of a national symposium, Glenwood Springs. Thorne Ecological Institute, Boulder, CO.

Abstract. A cartographic model was developed using a Geographic Information System to automate, display, and evaluate the cumulative effects of management activities in the Greater Yellowstone Ecosystem on free-roaming grizzly bear (*Ursus arctos horribilis*) habitat. Habitat conditions, such as plant feeding opportunities, concentrated protein food sources, cover availability, and habitat type diversity, were used to estimate the habitat quality of Bear Management Units (80,000-160,000 ha). Habitat quality coefficients were evaluated for applicability by comparing habitat values of various buffer sizes and shapes surrounding grizzly bear radio relocation sites with a similar number of randomly selected sites. The model provides for development of management strategies through testing for a series of management alternatives. The model can be used to evaluate what land uses have the greatest impact and the additive effect of proposed management scenarios.

Winn, D.S., and K.R. Barber. 1986. Cartographic modeling: a method of cumulative effects appraisal. Pages 247-252 in G.P. Contreras and K.E. Evans, eds. Proceedings - grizzly bear habitat symposium. U.S. Forest Service Intermountain Research Station General Technical Report INT-207.

Abstract. The basic assumptions and implications of developing a wildlife habitat cartographic model are discussed. A cartographic model and Geographic Information System were used to evaluate the cumulative effects of management activities on free-ranging grizzly bear (*Ursus arctos horribilis*) habitat within the Greater Yellowstone Ecosystem. The habitat characteristics associated with bear unit values, habitat diversity, and edge use were evaluated by comparing habitat conditions in various buffer zones surrounding grizzly bear radio location sites with a similar number of randomly located sites. The cartographic modeling process is outlined and the model's utility for evaluating management implications and research needs are summarized.

Winter, T.C. 1988. A conceptual framework for assessing cumulative impacts on the hydrology of nontidal wetlands. Environ. Manage. 12:605-620.

Abstract. Wetlands occur in geologic and hydrologic settings that enhance the accumulation or retention of water. Regional slope, local relief, and permeability of the land surface are major controls on the formation of wetlands by surface-water sources. However, these landscape features also have significant control over groundwater flow systems, which commonly play a role in the formation of wetlands. Because the hydrologic system is a continuum, any modification of one component will have an effect on contiguous components. Disturbances commonly affecting the hydrologic system as it relates to wetlands include weather modification, alteration of plant communities, storage of surface water, road construction, drainage of surface water and soil water, alteration of groundwater recharge and discharge areas, and pumping of groundwater. Assessments of the cumulative effects of one or more of these disturbances on the hydrologic system as related to wetlands must take into account uncertainty in the measurements and in the assumptions that are made in hydrologic studies. For example, it may be appropriate to assume that regional groundwater flow systems are recharged in uplands and discharged in lowlands. However, a similar assumption commonly does not apply on a local scale because of the spatial and temporal dynamics of groundwater recharge. Lack of appreciation of such hydrologic factors can lead to misunderstanding of the hydrologic function of wetlands within various parts of the landscape and hence mismanagement of wetland ecosystems.

Witmer, G.W. 1985. Cumulative impacts of hydroelectric development. Pages 22-27 in R.D. Comer, T.G. Baumann, P. Davis, J.W. Monarch, J. Todd, S. VanGytenbeek, D. Wills, and J. Woodling, eds. Issues and technology in the management of impacted western wildlife. Proceedings of a national symposium, Glenwood Springs. Thorne Ecological Institute, Boulder, CO.

Abstract. Despite legislative and administrative mandates that cumulative impacts be incorporated as an element of environmental impact assessment (EIA), governmental agencies and consultants have been slow to develop and utilize the necessary methodologies. Part of the problem lies in the definition of cumulative impacts, part lies with methodological difficulties, and part lies in the perceptual horizons of those assessing the impacts. Nonetheless, as land use and energy production expand and intensify, concern with cumulative impacts is increasing. In this paper, the extensive Columbia River Basin hydroelectric system is discussed relative to cumulative impacts to anadromous fish, big game, and other fauna. Several EIA methods are categorized, briefly reviewed, and contrasted with cumulative EIA. It is possible that a combination of existing methods can be used for cumulative EIA. To do so effectively, some additional concepts must be incorporated.

Witmer, G.W. 1986a. Assessing cumulative impacts to wetlands. Pages 204-208 in J.A. Kusler and P. Riexinger, eds. Proceedings of the national wetland assessment symposium. ASWM Tech. Rep. 1. Association of State Wetland Managers, Chester, VT.

Abstract (from the Introduction). The author reviews types of wetland impacts, what a standard environmental impact assessment (EIA) entails, and how it must be modified to allow for cumulative impact assessment (CIA). He also briefly reviews nine approaches to CIA and gives examples of some methods of particular potential or widespread use. It is probable that a combination of these methods can be used for CIA. Finally, he lists some areas needing improvement if CIA is to be successful and effective.

Witmer, G.W. 1986b. What are cumulative impacts all about? Pages 13-22 in E.D. Estevez, J. Miller, J. Morris, and R. Hamman, eds. Proceedings of the conference: managing cumulative effects in Florida wetlands. New

College Environmental Studies Program Publ. No. 38. Omnipress, Madison, WI.

Abstract. The growing concern over cumulative impacts is addressed. Definitions and types of cumulative impacts are discussed and examples given. Some methods for the assessment of cumulative impacts are referenced, but it is noted that such methods are in an embryonic state of development. The complex nature of wetlands makes them especially difficult to assess. Any method attempting to assess cumulative impacts must consider many additional factors beyond those of traditional impact assessment; extended time and spatial frame, flexible boundaries, adaptability, and aggregation of impacts are among these considerations. Research in key areas can help improve our ability to perform cumulative impact assessment.

Witmer, G., J.S. Irving, and M. Bain. 1985. A review and evaluation of cumulative impact assessment techniques and methodologies. Prepared by Argonne National Laboratory for Bonneville Power Administration. v.p.

Addition. This report identified alternative methodologies capable of assessing cumulative effects on species and habitats. Each method was evaluated for potential application in the Columbia River basin for assessment of cumulative effects of hydropower development. Eight general types of environmental assessment techniques were briefly reviewed and evaluated with respect to their abilities to identify impacts, quantify impacts, interpret impacts, communicate information, and assess cumulative impacts. The eight categories were ad hoc, evaluative, panels, checklists, matrices, mapping, networks, and models. Eleven specific methodologies were evaluated for their usefulness in assessing hydropower impacts in the Columbia River basin: Snohomish guidelines, instream flow incremental methodology, INTASA (U.S. Army Corps of Engineers), Swan River cumulative impact assessment methodology, Trinity Lakes assessment methodology, water resources assessment methodology, adaptive environmental assessment and management, cluster impact assessment procedure, habitat evaluation procedures, San Juan assessment methodology, and wetland functional values methodology. A description of these methodologies is provided with a discussion of their applicability to hydropower planning and licensing and their strengths and weaknesses.

Witmer, G.W., M.B. Bain, J.S. Irving, R.L. Kruger, T.A. O'Neill, R.D. Olsen, and E.A. Stull. 1988. Cumulative impact assessment: application of a methodology. Waterpower '87, vol. 1, 642-650.

Abstract. We expanded upon the Federal Energy Regulatory Commission's Cluster Impact Assessment Procedure to provide a practical methodology for assessing potential cumulative impacts from multiple hydroelectric projects within a river basin. The objectives in designing the methodology were to allow the evaluation of a large number of combinations of proposed projects and to minimize constraints on the use of ecological knowledge for planning and regulating hydroelectric development at the river basin level. Interactive workshops and evaluative matrices were used to identify preferred development scenarios in the Snohomish (Washington) and Salmon (Idaho) River Basins.

Although the methodology achieved its basic objectives, some difficulties were encountered. These revolved around issues of (1) data quality and quantity, (2) alternatives analysis, (3) determination of project interactions, (4) determination of cumulative impact thresholds, and (5) the use of evaluative techniques to express degrees of impact.

Young, D.L. 1986. Cumulative effects analysis of grizzly bear habitat on the Lewis and Clark National Forest. Pages 217-221 in G.P. Contreras and K.E. Evans, eds. Proceedings - grizzly bear habitat symposium. U.S. Forest Service Intermountain Research Station General Technical Report INT-207.

Abstract. An interagency work group derived a cumulative effects analysis process tailored to a selected bear management unit and using grizzly bear data from ongoing studies along the Rocky Mountain Front Range. Analysis is done by constituent element within a bear management unit, and a scoring system is used to assess each human activity's contribution to cumulative effects. Patterns of bear use (radio locations and observations gathered by Rocky Mountain Front Range grizzly studies) were analyzed to determine three zones of habitat effectiveness (high, moderate, low), which are used to display the results of the cumulative effects analysis. Thresholds were designated. Radiotelemetry data from the bear management unit gathered subsequent to the development of this cumulative effects analysis process have tended to verify the zones of habitat effectiveness determined with this analysis process.

Zinke, P.S. 1981. Cumulative impacts on watershed processes and soil productivity. Pages 22-35 in R.B. Standiford and S.I. Ramacher, eds. Cumulative effects of forest management on California watersheds. Univ. Cal. Agri. Spec. Publ. 3268. Berkeley.

Addition. This paper is concerned with the effects of cumulative impacts of human use on the surface condition of the watershed. The paper begins with a review that "integrates cumulative effects over historical time scales needed to develop the principles involved." Recent findings of the past fifty years are evaluated to describe how the concept of cumulative effects developed. The current status of knowledge of hydrologic, pedologic, and chemical processes is briefly summarized. Key indicators of undesirable effects are the amount of bare soil, acceleration of erosion rates, changes in surface runoff rates, and significantly reduced crop productivity. Hazard ratings can be given to soils based on soil depth, slope, stability of soil aggregates, rainfall amount, and vegetation density and may help predict impacts of human use. The predictability of cumulative effects with time also depends on recovery rate; land use changes may not always be adverse, given time, proper management practices, and adequate mitigation.

Zivnuska, J.A. 1981. The economics of cumulative effects. Pages 94-104 in R.B. Standiford and S.I. Ramacher, eds. Cumulative effects of forest management on California watersheds. Univ. Cal. Agri. Sci. Spec. Publ. 3268. Berkeley.

Abstract (from the Conclusion).

1. The social construct of cumulative effects in a regulatory framework is so poorly conceived that it cannot be identified to the degree necessary for meaningful analysis.

2. The work of biological and physical scientists is largely concentrated on identifying and understanding the total effects of man on the environment. Very little information is available that would make the quantitative estimates as to the extent and probabilities of occurrence of the joint product effects resulting from the two or more actions in an ecosystem, which are an essential basis for economic analysis of cumulative effects.

3. For all of the ambiguities in the notion of cumulative effects, it seems evident that the major costs and benefits involved must be extramarket in nature under existing policies and institutions. Thus, even if all other problems were solved, valid economic analysis of cumulative effects could not be carried out because of a lack of expression of the market values of these effects.

4. By definition, cumulative effects are the joint products of two or more projects or actions. From this it follows that the contribution of the individual project or action to the cumulative effects cannot be determined, for there is no cumulative effect from the project itself. Any allocation of costs or benefits of cumulative effects to individual projects must be arbitrary and in this sense indefensible.

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There is general agreement that ecological cumulative impacts (also known as cumulative effects) are a serious environmental challenge, but there is also some confusion as to what these impacts are and how to deal with them. This 145 paper, annotated bibliography reflects the status of ecological cumulative impacts assessment in the United States and Canada after ten years of development.

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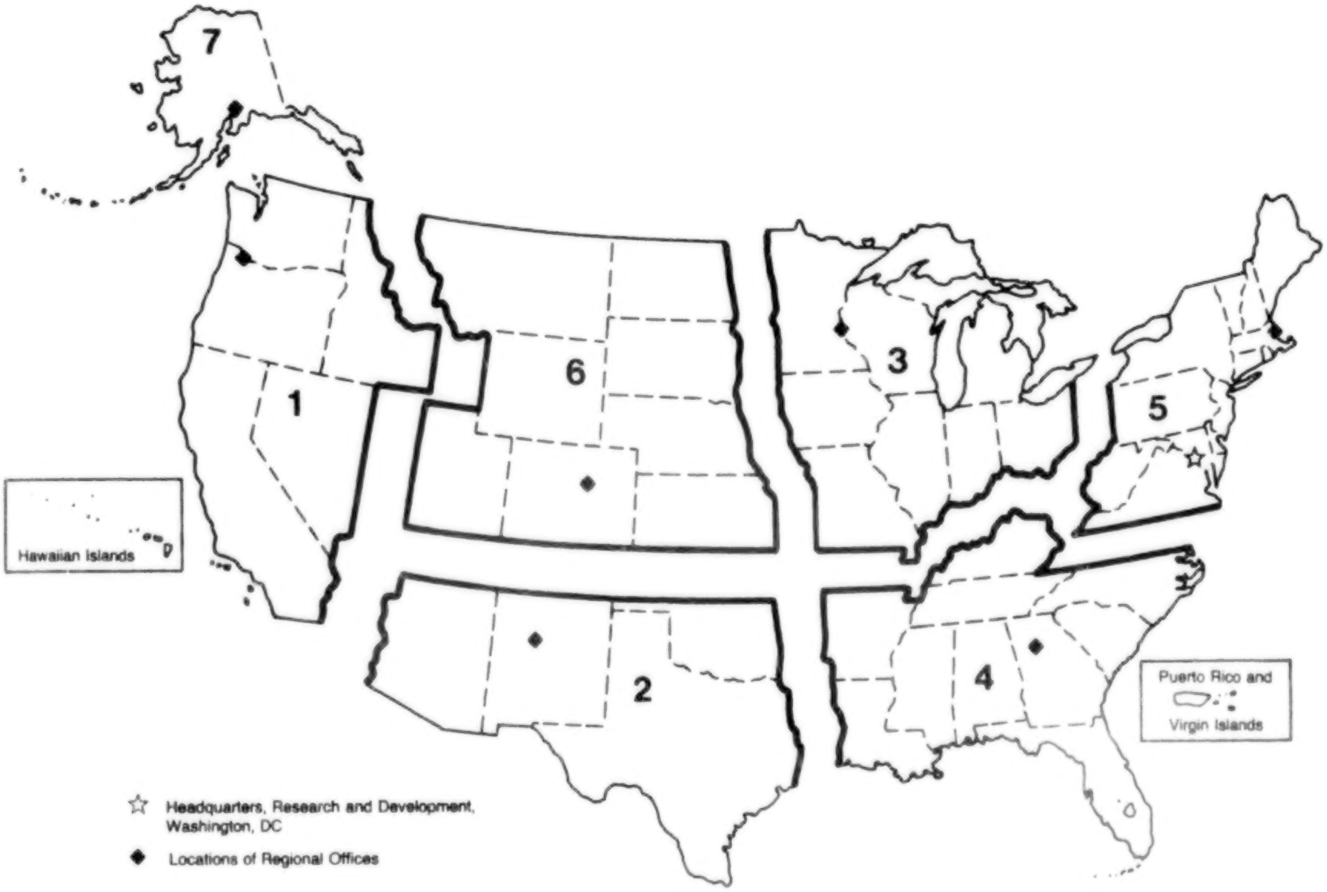
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